POWER PLANT ENGINEERING

Established Over 30 Years

VOL. XXX CHICAGO, JULY 15, 1926 No. 14

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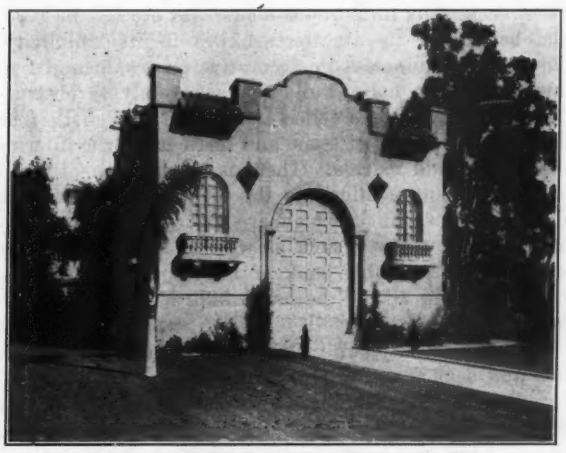


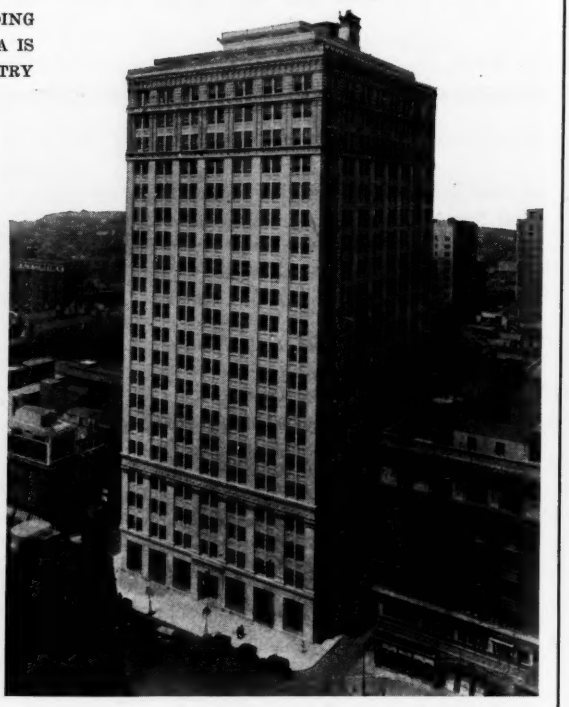
Appearances Are Deceitful

TO LOOK AT this dignified Spanish type residence with its well-kept garden one would not associate it with any but the most pleasurable happenings. Everything seems calm and orderly, the place fairly radiates contentment. Yet, it is whispered by those who pass along the avenue that, inside, all is not so peaceful as the outside seems to indicate. Shocking things are said to transpire within and more than once it has been rumored that innocent little amps have been switched and forced out of their ohms by cruel snapping volts. Other reports are current but it is difficult to place the charges —nobody is ever seen entering the building, yet it is claimed that all those that do are converted to the ways of the place and leave directly. Then, too, it is well guarded. Transients attempting to gain entrance are promptly arrested.

Mysterious doings, these, but entirely within the law for this building is none other than the Melrose automatic substation of the Los Angeles Railway Corporation where high voltage alternating current is converted to direct. Architectural design, it will be noted, was not the least important consideration in its construction, which is interesting because that phase of power plant design is discussed in some detail on page 793 of this issue.

New Atlantic Building Plant Burns Fuel Oil

NEW POWER PLANT SERVING THE OFFICE BUILDING OF THE ATLANTIC REFINING CO. IN PHILADELPHIA IS ONE OF THE FINEST OF ITS KIND IN THE COUNTRY



AMONG THE MANY new office buildings recently erected in the city of Philadelphia one of the finest and most modern in its appointments is the Atlantic Building which rises 21 stories above the street level at the intersection of Spruce and Broad Streets. This building, which is owned by the Atlantic Refining Co., and whose offices occupy its nine upper floors, was erected in 1923. The beauty of its architecture lies in its simplicity. There are no unnecessary decorative or ornamental features, which, in many buildings, serve only as obstructions to light and are collectors of dust and dirt. The exterior is of Benedict stone and terra cotta, the interior of concrete and marble. There is a minimum of wood trim, this being confined to the door and window sash and partitions, all of which are mahogany. Wood exposed to the weather, such as window sills and frames, is cypress. A double bank of high speed electric elevators, nine in all, of the latest improved type, are arranged efficiently for both local and express service.

Serving this structure with light, power, refrigeration and heat is a power plant which in every way conforms to the high standards of the building itself, not only as regards the arrangement and type of equipment installed but also in the manner in which it is operated. This power plant is located in the sub-basement and, although it is subject to the same limitations as regards headroom that characterize most office buildings, it presents an exceedingly attractive appearance throughout.

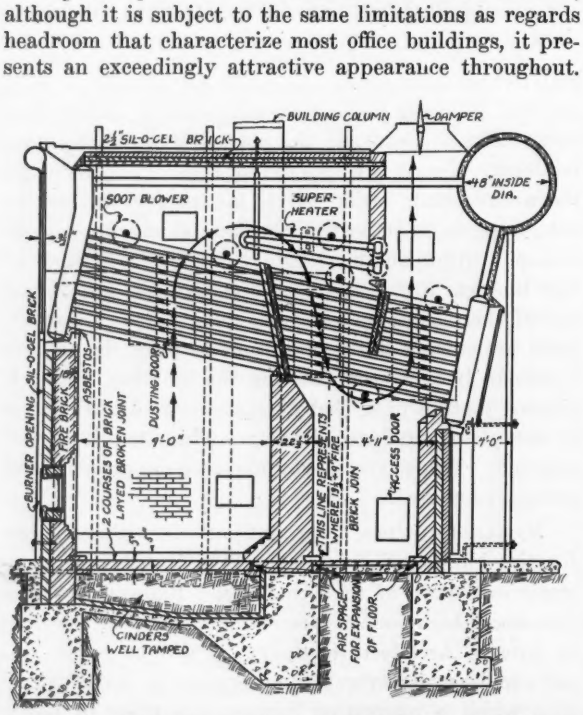


FIG. 1. THE BOILERS ARE OF THE CROSS DRUM, VERTICALLY BAFFLED TYPE, EQUIPPED WITH TWO OIL BURNERS EMPLOYING MECHANICAL ATOMIZATION

The general arrangement is shown in Fig. 4, the plant consisting of a boiler room, engine room, refrigerating room and pump room. These are all located on the same level making the pipe runs as simple and direct as possible. Steam is generated in three 254-hp. water tube boilers and electricity by three 250-kw. engine-driven generators. The refrigerating equipment actually installed in the power plant is provided only for drinking water cooling purposes. The refrigerating machinery serving the restaurant on the 21st floor is installed at that point.

BOILERS ARE OIL FIRED

Boiler equipment installed consists of three Edge Moor cross-drum, vertically baffled water tube boilers, each rated at 254 hp. capacity and arranged for burning fuel oil. Originally the designers had thought of using coal as fuel and, to this end, space for coal bunkers has been provided, but the convenience and cleanliness of fuel oil proved so attractive that the oil burning equipment was decided upon.

The three boilers are set separately in one row with the building columns between. A cross-section of one of the boilers is shown in Fig. 1. The steam drum, which is 4 ft. in diameter by about 10 ft. long, is located at the rear and is connected to the front and rear headers by horizontal and vertical circulating tubes. The vertical baffling is arranged so as to provide three gas passages. Foster superheaters are installed in the space above the second pass.

Each boiler is fitted with 6 units of Vulcan soot blowers, Foster non-return valves, Consolidated safety valves, Yarnall-Waring and Homestead blowoff valves and Re-

liance water columns. The water level in the boilers is regulated automatically by Copes feed water regulators. Bailey boiler meters are provided on each boiler. As may be noted from the accompanying photographs, the boiler installation is exceptionally neat and clean. The boiler fronts above the burner section are painted white and the front columns faced with white tile.

The furnaces are large so as to insure efficient combustion and are lined with 13½ in. of firebrick at the front and sides and have a floor of firebrick 5 in. thick. The bridge wall, which is of firebrick 22½ in. thick, is located 9 ft. back of the front wall.

Gases of combustion are removed from the boilers through a tapered steel breeching installed above the boilers which in turn discharges to the stack which runs 21 stories upward through the building.

Atomization of the fuel is accomplished mechanically by means of the Peabody system of oil burning. Two burners are fitted to each boiler. Fuel oil is stored in two 5000-gal. horizontal cylindrical tanks installed one on each side of the oil pump room. These tanks which are 19½ ft. long and 7 ft. in diameter, are installed in a concrete housing which, after the tank was in place, was packed with sand. To maintain the oil at the proper viscosity for efficient pumping in cold weather, each tank is provided with 15.9 sq. ft. of steam heating surface.

Two 1½-in. suction lines are provided; one a low suction line taking suction four inches from the bottom of the tank and the other, the high suction line, which extends to within 11 in. of the bottom.

Fuel oil is removed from the tanks by either of two duplex piston pumps 5¼ by 2¾ by 5 in., made by the National Transit Co., with Elliott twin strainers in both the suction and discharge lines. The oil commonly used varies between 19 and 23 deg. Be. For proper burning, this is heated to a temperature of 158 deg. F. by means of two Griscom-Russell straight tube oil heaters, before passing into the burner lines. An air chamber constructed from a 10-ft. length of 10-in. extra heavy pipe is placed on the burner line to eliminate the pulsations caused by the pumps.

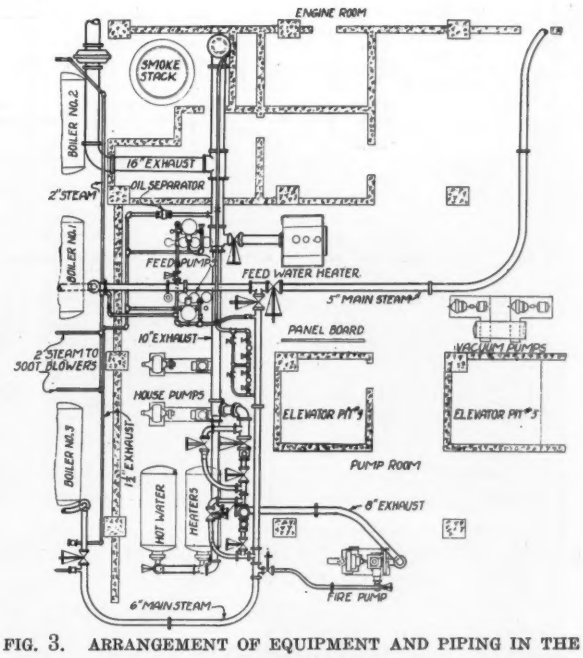


FIG. 3. ARRANGEMENT OF EQUIPMENT AND PIPING IN THE PUMP ROOM

An interesting and highly desirable feature of the oil burning system is the remote control equipment for shutting off the oil supply at the burners or at the oil pump room in case of accident. In case of fire or explosion, which would render the boiler room inaccessible, the fuel supply may be shut off from the engine room. At this point a small panel is installed on which are mounted control valves, one for each of the three boilers and a fourth for the main fuel oil pump. The system operates by air pressure through air-operated valves on the oil lines. The control on the main oil pump is on the steam line. If this control is operated, an air-operated valve shuts off the steam to the oil pumps, thus stopping it instantly.

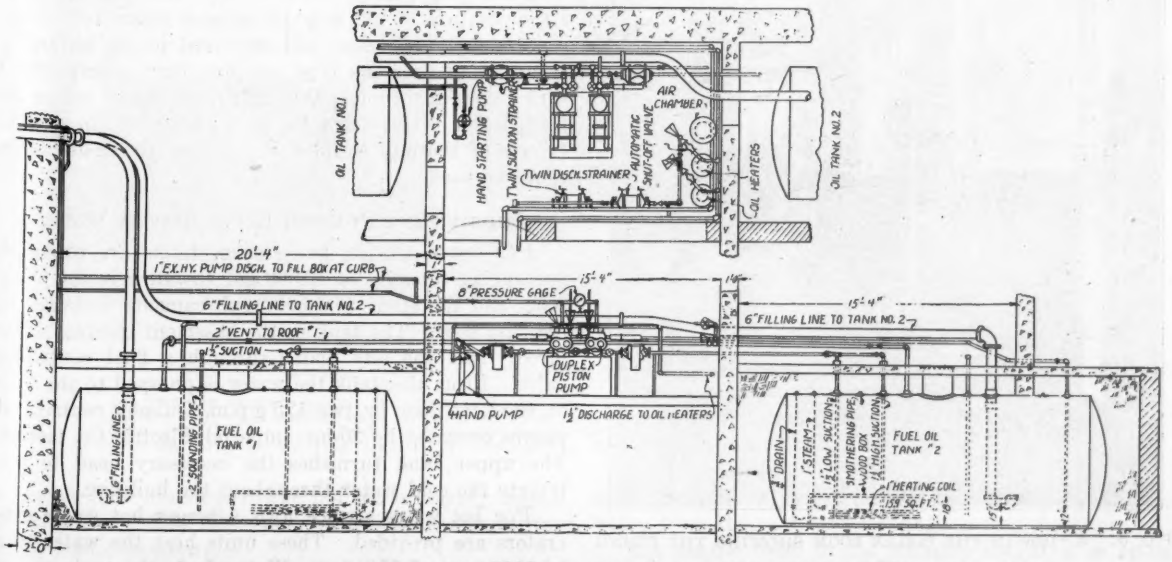


FIG. 2. FUEL OIL IS STORED IN TWO 5000-GAL. TANKS, ONE ON EACH SIDE OF THE PUMP ROOM

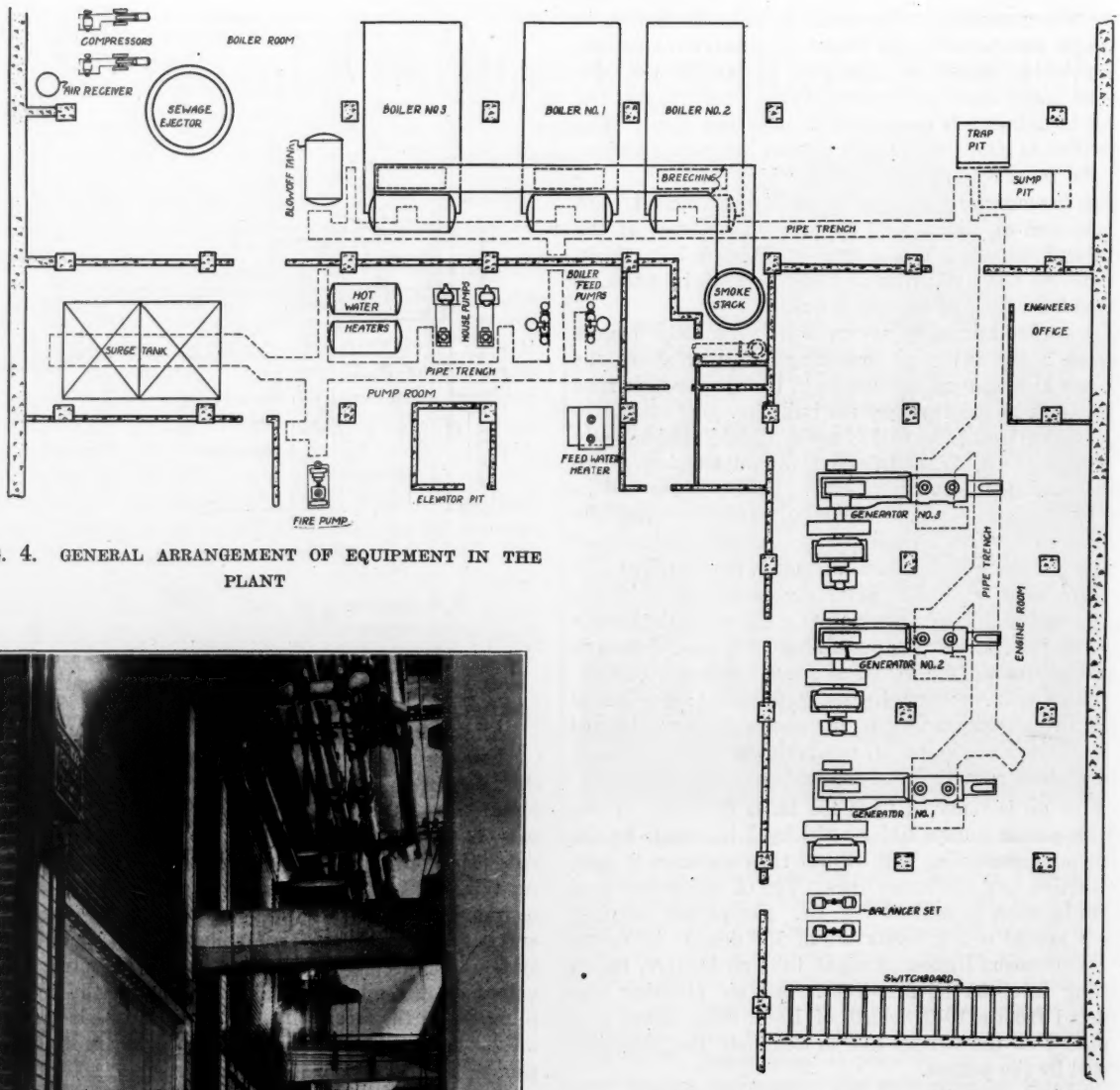


FIG. 4. GENERAL ARRANGEMENT OF EQUIPMENT IN THE PLANT

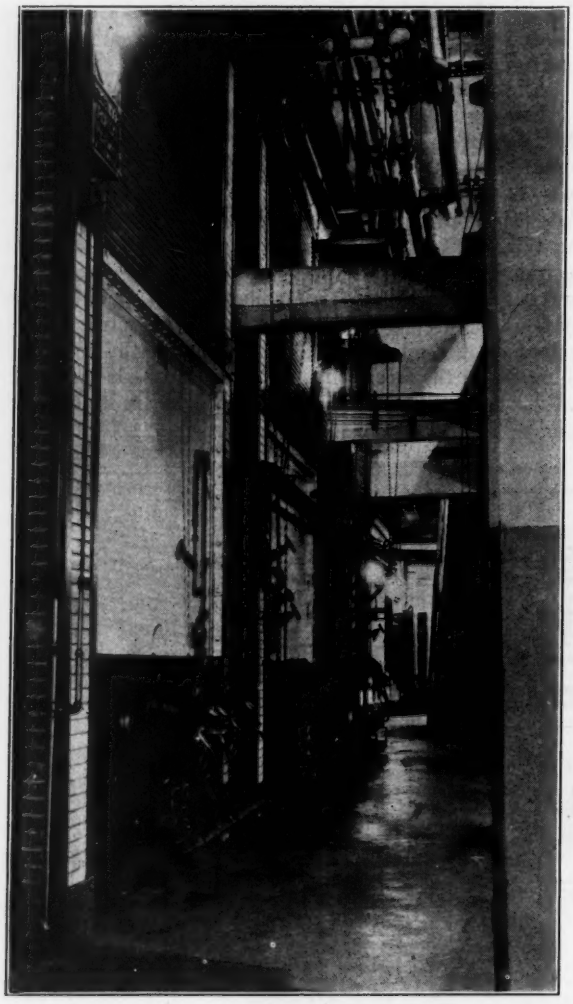


FIG. 5. A VIEW IN THE BOILER ROOM SHOWING THE FIRING AISLE

Boiler feed water, which is city water, is heated to a temperature of 212 deg. by exhaust steam in a Cochrane open type heater, and delivered to the boilers by either of two marine type, simplex Dean pumps fitted with Copes governors. Ordinarily the water enters the feed heater direct from the city mains but, in case of failure of the city supply, water from the house tanks could be used.

Heating and Pumping House Service Water

For house service, two storage tanks are provided, one having capacity of 12,000 gal. installed in the pump room and the other of 16,000 gal. capacity installed on the 21st floor. The tank in the basement receives water direct from the city mains through a float controlled valve. From this tank the water is pumped to the tank on the 21st floor by two 125-g.p.m. Quimby centrifugal pumps operated by 20-hp. Imperial Electric Co. motors. The upper tank furnishes the necessary head to distribute the cold water throughout the building.

For hot water service, two Alberger hot water generators are provided. These units heat the water to a temperature of 150 deg. Water from the tank on the

21st floor enters the heaters at the bottom and, after being heated by virtue of the difference in density between the hot and cold water, passes up to the 20th floor where the line branches to the hot water supply mains. At the lower end of the supply mains the water returns to the heater as shown.

For fire protection, a 750-g.p.m. 2-stage, Cameron pump driven by a London steam turbine is installed. The discharge line from this fire pump is connected to the line leading from the roof tank to the hot water generators, check valves being installed to prevent the water from the roof tank backing up into the pump.

The engine room in the Atlantic Building, in spite of the rather low ceiling, is exceedingly attractive.

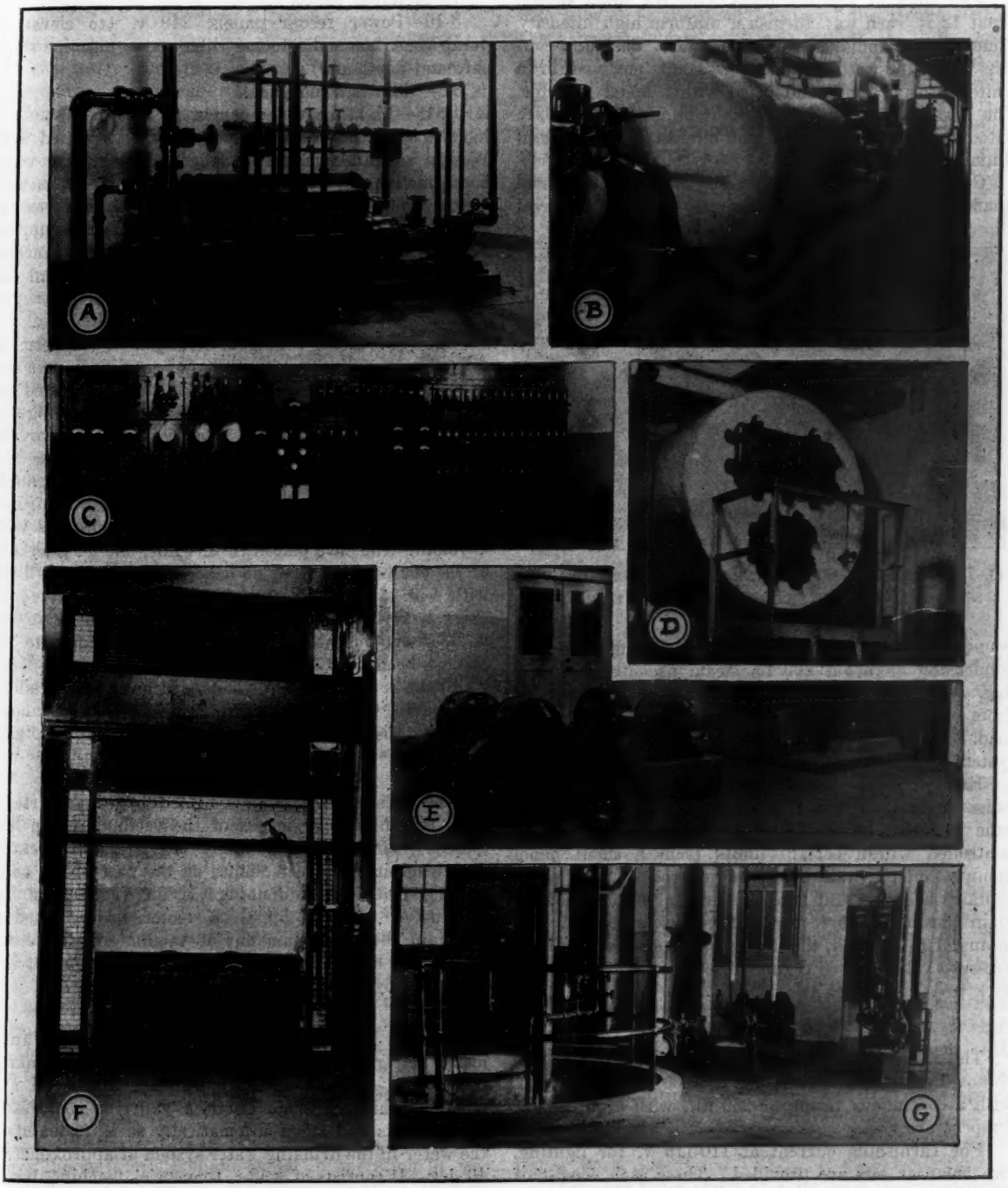


FIG. 6. RANDOM VIEWS IN THE POWER PLANT OF THE ATLANTIC BUILDING

A. The dry vacuum pumps for the heating system. B. One of the hot water generators for building service. C. The switchboard consists of 15 panels, all fitted with air break switches and circuit breakers. D. An open feed water heater heats the boiler water to 212 deg. E. Two balancer sets provide 110 v. for lighting service. F. One of the three Edge Moor boilers. G. The sewage ejector.

Everything is spic and span. Except for the lower five feet of the walls, which are painted a light olive, the ceiling and walls are white as is also all the piping. The floor is of cement.

Two rows of lighting units with the units spaced about 12 ft. each way furnish a uniform high intensity illumination throughout the entire room. Each unit consists of a 150-watt incandescent lamp, enclosed in a white diffusing globe and fitted with a metal reflector. The perfect diffusion of the light eliminates all glare without detracting from the high intensity of the general illumination.

Generating equipment consists of three Universal unaflow engines made by the Skinner Engine Co., direct

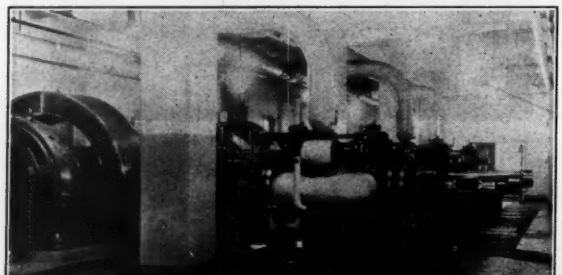


FIG. 7. THREE UNAFLOW ENGINE-DRIVEN GENERATORS FURNISH ELECTRIC CURRENT FOR POWER AND LIGHTING

connected to d.c. generators. The engines operate non-condensing on about 200 lb. steam pressure with 100 deg. superheat, normally against a back pressure of from one to two pounds, depending upon the heating load. Each unit is fitted with the standard Skinner system of lubrication and with Wyoming piston traps.

Exhaust steam is used for heating purposes and any excess is discharged to the atmosphere through a Cochrane back pressure valve. The back pressure can be controlled within certain limits from a small panel mounted on the wall in the engine room. This panel contains a switch and two pressure gages, one showing main steam pressure, the other, back pressure. By means of this switch, the degree of opening of the back pressure valve can be regulated, but in no case can the back pressure exceed two pounds.

Electrical Features

The main generators are General Electric Co. machines, Type LD-10, 8 pole, 250 v., 1000 amp., 200 r.p.m. with a continuous rating of 250 kw. with a 50 deg. C. temperature rise.

For furnishing current at 110-115 v. for lighting, two balancer sets are provided. These each consist of two 15 kw., 125 v., 120 amp., type R-G-29 G. E. generators. The rating of each set is 24 kw. when operating at 1700 r.p.m. and with 192 amp. in the neutral.

Generation and distribution of current is controlled by means of a 15-panel switchboard built by the Walker Electric Co. of Philadelphia. The panels are arranged as follows:

1—Swinging bracket for voltmeter.
2—Generator panel (Gen. No. 3).
3—Generator panel (Gen. No. 2).
4—Generator panel (Gen. No. 1).
5—Balancer set No. 1.
6—Balancer set No. 2.
7—Metering panel.
8-10—Power feeder panels, 240 v. (to elevators, pump room, ammonia room, boiler room, machine shop, cafe and penthouse).
11—Main lighting panel.
12-16—Lighting feeder panels.

The board is constructed of black slate, fitted with Weston volt and ammeters, Sangamo integrating watt-hour meters, Esterline-Angus recording wattmeters, Cutter Co. I. T. E. circuit breakers and G. E. rheostats. All conduit and mechanism extending above the top of the board is concealed behind sheet steel paneling mounted between the top of the switchboard and the ceiling.

Steam Piping

The main steam piping is arranged in the form of a loop, so as to insure continuity of service, in case one part of the line becomes damaged or must be isolated for repairs. A 5-in. high pressure steam line running the entire length of the engine room is installed near the ceiling above the engines. At one end, where the line passes through the pump room, this main line reduces to 4 in., while the other end continues as a 5-in. line directly back to the boilers. Separators equipped with Wyoming traps are placed in this line, one on each side of the engines. The engine headers are 4-in. lines fitted with 4-in. extra heavy cast steel gate valves. Five-inch extra heavy C. S. gate valves are also placed in the main steam line at the point where the headers to the engines branch off.

Steam is taken from the boilers through 5-in. headers, each having a 3-ft. radius expansion loop, and connecting into the main steam header through a 5-in. gate valve.

Steam Heating System

The Atlantic Building is heated by exhaust steam from the engines by means of the vacuum return line system. This system is highly effective and operates with a minimum of attendance on the part of the engineering force. Two Jennings Hytor vacuum pumps, each driven by a 7½-hp. G. E. motor, are provided to maintain the proper amount of vacuum in the return line and to handle the condensate. This equipment was furnished by the Nash Engineering Co.

Ice Water Service

Another interesting feature of this plant is the automatic refrigerating machine for cooling the drinking water used throughout the building. This is an ammonia machine, with an electrically driven compressor which starts and stops automatically so as to maintain the water in the drinking water system at approximately 40 deg. It consists of a 12-t. Brunswick machine driven by a 20-hp. G. E. motor.

Water is pumped through the building by either of two Deming Triplex pumps operating at 155 lb. pressure and driven by a 3.5-hp. Sprague electric motor.

City water is admitted to the cooling system through a Puro filter which removes all suspended matter and then passes through the float control tank to the cooling tank. This arrangement is shown in Fig. 8. The water level in the float control box, it will be evident, is the

same as that in the cooling tank. A float in the control tank automatically regulates the amount of city water coming into the tank. This refrigerating equipment was installed by the Goetz Ice Machine Co. of Philadelphia.

Sewage Ejector

Since the power plant is located considerably below the city sewer level, it is necessary to provide a means of removing any sewage that accumulates there. This is done by means of a sewage ejector installed by the Shone Co. of Chicago, and which is operated by compressed air. When the sewage accumulating in a closed receiving tank reaches a certain level, compressed air is admitted, thus forcing the sewage up into the city sewer. Compressed air for this system, which operates entirely automatically, is furnished by two electrically driven Ingersoll-Rand air compressors. This equipment is shown in Fig. 6G.

The Elevator System

The elevators at the Atlantic Building are Otis elevators of the latest type, all equipped with micro levelers, which automatically level the car as it comes to a stop at a floor. There are several unusual features in the operation of the elevators which may be of interest particularly to those having elevators under their charge. As in all other skyscrapers, it sometimes happens in the Atlantic Building that an elevator car stops between floors and will be out of control except to the man in the penthouse. He, of course, can lower or raise the car by hand operation of the elevator controller in the penthouse, but ordinarily he has no means of telling where the car is located in the shaft. To take the car to the nearest floor level and get the passengers off in the quickest possible time is of the utmost importance. In order to accomplish this, Walter Nowell, who has charge of all elevators in the building, has devised and constructed an indicator for each elevator. These indicators are located in front of each machine and can be seen while operating the controller. By means of this indicator, the exact location of the car is shown and the leveling at any floor can be done most accurately from the penthouse. The indicators also show when the elevator operator's signal is late or early in going on and informs the man in the penthouse whether the operator has the signal button in the car "off" or "on."

The indicators consist of an endless chain carried over two sprocket wheels arranged vertically, to which are affixed tabs carrying the numbers of the floors. This arrangement is driven from the signal machine located in the secondary sheave loft. As the sprockets rotate, the tabs passing in front of an indicating window in the housing covering the device show the location of the car in the shaft.

Another device invented by Mr. Nowell is that which keeps the elevator flashlight signal in operation in case the preceding car ignores the signal. It often happens that a person signals a car just a moment before or just as the car reaches his floor. Often the elevator operator doesn't see the flash or ignores it and the signal goes "off." Then, when the next car fails to stop, the person waiting becomes impatient and complains of poor service. It is not until several cars have passed that he finally presses the button, thus resetting the signal.

With Mr. Nowell's device the possibility of such an occurrence is eliminated because, if the first car passes the signal for any reason whatever, the signal remains operative until the next car arrives. The construction of this device is quite ingenious, making use of a solenoid and a brass tube with a steel ball rolling through it. The tube is balanced on trunnions and is operated by the solenoid which pulls one end of the tube down, causing the ball to run to the end of the tube. At the same time the motion of the tube causes a mercury switch to make contact which prevents the signal from being reset on the floor at which the button has been pushed, the previous car having passed without stopping.

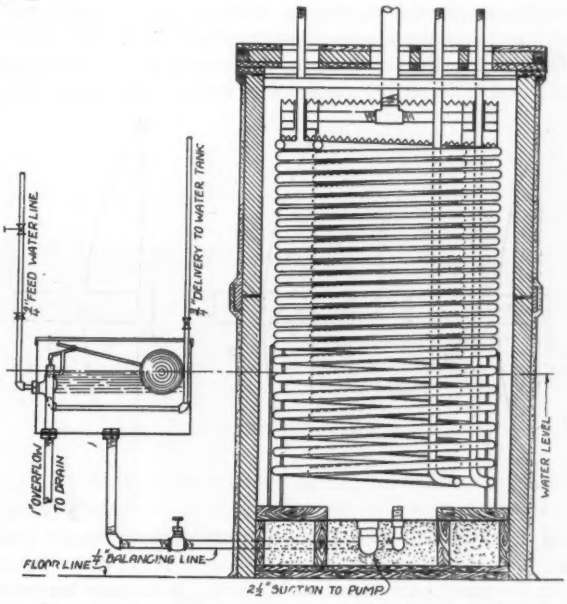


FIG. 8. THE COOLING TANK AND WATER REGULATING DEVICE FOR DRINKING WATER SERVICE

The magnet which is connected with the reversing switch on the elevator controller gets current only when the car is in operation.

Conclusion

In concluding this article, we wish again to emphasize the spic and span appearance of this plant, and the admirable manner in which Harry Charles, the chief engineer, has trained his operating force. Everybody connected with the plant is enthusiastic about it and seems to take a real interest in his work. Each man, in addition to his regular operating duties, is held responsible for a certain amount of equipment. He must see to it that this equipment is always kept in a top notch condition of efficiency and that it is always clean and polished. The operating force does all the work—all the cleaning and painting, as well as all minor repair work.

There are three shifts of 8 hr. each, each consisting of an engineer, a fireman and an oiler. There is quite a spirit of rivalry between the men in keeping the equipment in their care in the best condition.

For assistance in the collecting of data for this article and for privileges extended in furnishing drawings, we wish to express our indebtedness to Andrew Johnstone, manager of the Atlantic Building, and to Harry Charles, the chief engineer.

Critical Speeds of Shafts and Heavy Rotors

ACTUAL BEHAVIOR CAN BEST BE UNDERSTOOD BY VIEWING CRITICAL SPEEDS AS SPEEDS AT WHICH RESONANT VIBRATIONS DEVELOP. BY BURT L. NEWKIRK*

ROTORS of heavy machinery, in their critical speed behavior, do not follow very closely the indications of the common theory of shafts. In the following notes the conclusions of this common theory are briefly stated. A different point of view is then suggested and the actual critical speed behavior of shafts is explained as a phenomenon of resonant vibration.

Figure 1 represents a rotating shaft having negligible weight, supported rigidly in bearings at the ends, and carrying a heavy disc mounted eccentrically. The point B is on the line of bearing centers, S is on the shaft axis and G is at the center of gravity of the disc. The

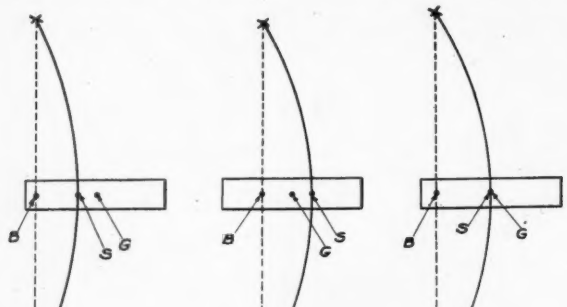


FIG. 1. SHAFT OF NEGLIGIBLE WEIGHT CARRIES HEAVY DISK MOUNTED ECCENTRICALLY, B REPRESENTING LINE OF BEARING CENTERS, S THE SHAFT AXIS AND G CENTER OF GRAVITY OF DISK

FIG. 2. SHAFT AND DISC ARRANGEMENT WITH G LYING BETWEEN B AND S

FIG. 3. PERFECTLY BALANCED ROTOR (THEORETICAL CONDITION) IN WHICH S AND G COINCIDE

figure shows the shaft rotating and bowed out by the centrifugal force of the unbalance caused by the eccentrically mounted disc. We assume that the shaft, when not rotating, is straight so that B and S coincide. We assume also that when the shaft rotates it deflects so that B, S and G are in a straight line, the shaft bending more or less according to the speed.

Reasoning on the basis of these assumptions we should conclude that the deflection of the shaft should increase as the speed increases until the shaft is stressed beyond its elastic limit and bent or broken. According to this reasoning there is some definite speed at which the shaft should bow out to destruction, even though the distance SG were extremely small; that is, there is a definite speed at which destruction of the rotor should occur with even the minutest unbalance. This speed is called the critical speed. Its value depends on the rigidity of the shaft and the weight of the disc but not on the amount of the unbalance. That is, a stiff shaft carrying a light load has a high critical speed, and a flexible shaft carrying a heavy load has a low critical speed.

*Research Laboratory, General Electric Co.

GENERALLY ACCEPTED THEORY OF CRITICAL SPEED

Reasoning in this way it was believed and asserted at one time that the critical speed of a rotor is the absolute maximum speed above which the rotor could not be run.* After DeLaval had succeeded in making turbines run far above their calculated critical speeds the theory was extended to explain the possibility of such operation. If it is assumed that the center of gravity G lies between B and S (Fig. 2) we would conclude that the shaft might run above critical speed in this configuration and that the shaft bends less and less as the speed increases; also that for very high speeds the distance BG decreases until B and G nearly coincide. If, however, a shaft running in this configuration at high speed should decrease in speed gradually, the deflection BS would increase so that the shaft should be destroyed

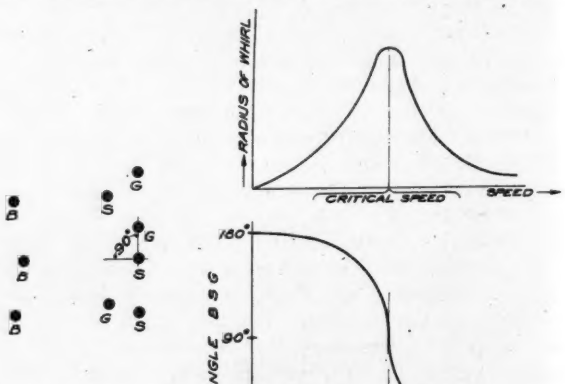


FIG. 4. IN PRACTICE, B, G, AND S TAKE THE RELATIVE POSITIONS SHOWN HERE, INSTEAD OF THOSE ASSUMED IN FIGS. 1—3

FIG. 5. DIAGRAMS SHOWING RELATION OF SPEED TO CHANGING RADIUS OF WHIRL AND ANGLE BSG

just before it gets down to that speed which has already been called the critical speed.

THEORY OF PERFECTLY BALANCED ROTOR

Suppose now that a rotor were perfectly balanced (Fig. 3). Of course, no rotor could be perfectly balanced, but we may assume an ideal rotor for the purpose of explaining the theory. In this case S and G would coincide. Reasoning along the line indicated above we would conclude that the shaft would not bow out at all, at any speed above or below the critical speed but that, at the critical speed it might whirl, with the distance BS anything whatever, so long as the elastic limit of the shaft is not exceeded. This view of the critical speed forms the basis for calculation of the critical speed of actual rotors. We assume them to be in perfect balance, and calculate, by a series of approxi-

*Föppl, Vol. ii, Tech. Mech. IV, p. 273, 6th ed.

mations, if necessary, the speed at which the centrifugal forces exerted by the bucket wheels or other loads just balance the elastic restoring force of the shaft. In this calculation the deflection at the middle of the shaft may have any convenient value, but, other than this, the shape of the bowed shaft is determined by the centrifugal forces and the stiffness of the shaft.

How Does Behavior of Real Shaft Follow Theory?

Now let us inquire how nearly a real shaft follows in its behavior the indications of this simple theory. A small rotor, such as one might use for a laboratory study of shaft behavior, unless it is very well balanced, agrees well with the theory. Assuming that the model rotor runs on self alining ball bearings, the points of support of the shaft are well defined, the supports may be made rigid and the critical speed can be calculated quite accurately. If the model be started and run at an increasing speed it will begin to whirl, and at about the calculated critical speed it will become very rough and wreck itself unless means are provided to limit the radius of whirl to a safe value. This is on the assumption that the model is not well balanced. If, however, the model is given a refined balance, it will become excessively rough in passing through its critical speed and it may even be kept running indefinitely at its critical speed without doing itself any damage. If, instead of running on ball bearings, it is run on journal bearings of ordinary proportions, it may be so well balanced that it will run continuously at critical speed with little more vibration or whirling than it exhibits at other speeds. Since no balancing can be perfect, the fact just stated is contrary to the theory explained above, which indicated that a rotor, unbalanced to the minutest degree, should be wrecked if run at critical speed.

This discrepancy is due to the failure of the theory to take account of a resistance to the whirling motion, which resistance exists even when rotors run on self aligning ball bearings and is very marked in plain bearings. Because of this resistance, the three points B, S and G do not lie in a straight line as they were assumed to, but in relative positions indicated in Figure 4. The upper configuration shows the relative positions with the model running below the critical speed, the middle one shows the configuration at the critical speed and the lowest one shows the configuration for a speed well above the critical. Plots of the changing radius of whirl and angle BSG would have the forms shown in Fig. 5. With good balance, the peak of the upper curve would flatten out, and with self alining ball bearings the lower curve would be steeper near the critical speed. The theory of critical speeds which is now commonly accepted is extended to take account of this resistance to the whirling motion of the shaft, and experiments show a fair agreement between the indications of this extended theory and the behavior of model rotors.

When we inquire further as to the agreement between this extended theory and the behavior of rotors of heavy machinery, further important discrepancies appear. Heavy rotors are well balanced and run on journal bearings. Consequently they should and do run without serious disturbance at their calculated critical speeds. Owing to the length of the journal bearings the effective length of the rotor is not closely determined; also the bearings, if long, may exert some stiffening effect on the rotor. Another important departure from the conditions assumed in theory is in the lack of rigidity of the bearing standards and their structural supports. Theory assumes the rotor to be so rigidly supported at the bearings that their yield when their load is applied is negligible compared with the deflection of the shaft at its middle. This condition is not satisfied in case of the heavier rotors. The yield of their bearings when the load is placed upon them is of the order of magnitude of the shaft deflection and the bearing supports are more rigid vertically than horizontally. This affects profoundly the critical speed behavior of the heavier rotors. Briefly stated, the heavier rotors do not vibrate or whirl at all at their calculated critical speeds. At some speed lower than the calculated critical speed, they will, if out of balance, vibrate in a vertical plane while running. At some lower speed still they will, if they are out of balance, vibrate in a horizontal plane. At other speeds unrelated to the calculated critical speed vibration may build up in some part or other of the structure.

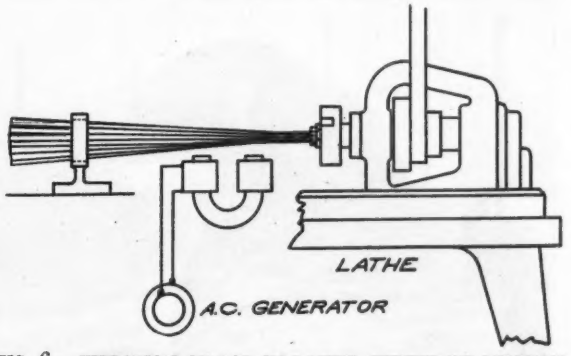


FIG. 6. VIBRATION OF ROD IN LATHE, EITHER BY MECHANICAL MEANS OR BY ELECTROMAGNET, IS ABOUT THE SAME WHETHER ROD IS ROTATING OR NOT

Practical Method for Demonstrating Shaft Behavior

To understand this behavior try the following experiment. Chuck a rod in a lathe and let it pass through a guard ring to prevent lashing out as in Fig. 6. Now pull the rod aside, let it spring back and observe the path of the tip. If the rod is quite round it will vibrate mainly in a plane, perhaps with some variations. Now run the lathe, to make the rod rotate, and set it into vibration as before. You will find that the rod will vibrate when rotating just about as it did when not rotating.

This may be tested in another way by exerting upon the rod a periodic force due to an electromagnet. The electromagnet should be energized by alternating current, the frequency of which can be varied at will. Find the frequency that will build up (plane) resonant vibration in the rod and it will be seen that such resonant vibration will build up whether the lathe is running or not and that the speed at which the lathe runs has no effect upon the frequency of the resonant vibration of the rod.

This suggests a different point of view for the inter-

pretation of critical speeds. The slight unbalance of a rotor exerts a rotating force. This force may be resolved into horizontal and vertical components which are periodic, following the sine law. When the speed of a turbine corresponds with the natural frequency of vibration of the rotor on its somewhat elastic bearing supports a resonant vibration sets in. The elasticity of the support being somewhat different horizontally and vertically, the natural frequencies will be somewhat different for horizontal and vertical vibrations. Consequently the running speeds at which such vibrations develop will be different. The amplitudes of vibration will be determined by the amount of unbalance and the degree of damping resistance. This damping resistance is due to action of oil in the bearings and to the working at joints and the like.

due to the elasticity of the bearing supports which cannot be calculated from the design.

Apparatus Developed for Studying Resonant Frequencies

Figure 7 shows a means we have employed to study the resonant frequencies of a turbine generator set. The calculated critical speed of this three bearing rotor was 2260 r.p.m. Vibrations were noted at the generator end when the unit ran at about 1550 r.p.m. and at the turbine end at about 1250 r.p.m. The device strapped to the generator contains an unbalanced rotor driven by a variable speed motor. By varying the speed of the motor, resonant vibrations could be set up, and it was found that the frequencies of these vibrations corresponded very well with the speeds at which vibration

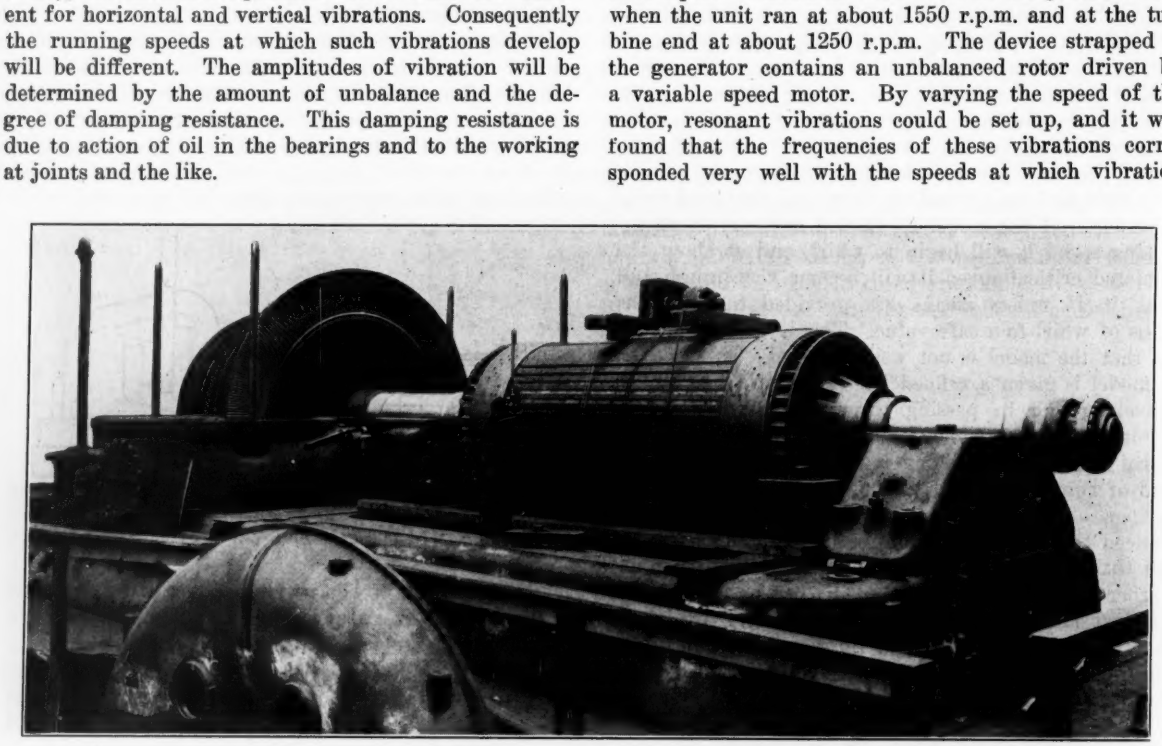


FIG. 7. MECHANICAL VIBRATOR ATTACHED TO GENERATOR ROTOR DETERMINES RESONANT FREQUENCIES

Critical Speeds Are Phenomena of Resonant Vibration

From this point of view, critical speeds are simply speeds at which the rotating centrifugal force due to the unbalance may cause resonant vibration. These speeds may or may not coincide with the calculated critical speeds of rotors, depending on whether the bearing supports are sensibly rigid, whether the bearings are long with small clearances or short with large clearances and, in general, whether the other assumptions made in the calculation of the critical speed correspond with the facts.

Resonant vibrations may build up in other parts of the structure of a machine and though the shaft may not participate to any great extent in the vibration, it usually furnishes the stimulus. For example, a three bearing rotor may not be entirely straight, and in rotating it would then exert periodic forces on its bearings. Such forces may set up resonant vibrations at certain speeds, which on this account have been called critical speeds.

The calculated critical speed of a heavy rotor is likely to be considerably higher than the speeds at which the shaft will vibrate if unbalanced, the difference being developed in operation of the unit. No resonant vibration with a frequency of 2260 per minute developed, but there was resonance in a vertical plane at 1875 per minute, which was above running speed, in a horizontal plane at 1550 per minute and near 1250 per minute.

The facts presented above seem to justify the view that critical speed phenomena, as contemplated in the older theory, do not occur in the operation of heavy rotors. It is undoubtedly useful to continue to calculate critical speeds as part of the design, the results of such calculations giving a valuable indication of the relative stiffness of a rotor but the great divergence in behavior from that indicated by the theory must not be overlooked. The actual behavior of a rotor can best be understood by viewing its "critical speeds" as speeds at which resonant vibration will develop if the rotor is unbalanced. The possibility of resonant vibration due to stimuli, other than the unbalance, must also be kept in mind.

WHEN YOU'RE SELLING, play your aces. The prospect probably knows all your low cards and always holds a winning hand until you have convinced him and sold him. So play your aces!

Modern Furnace Walls Last Longer

At First Air-cooled, and Later, Water-cooled Walls, Have Revolutionized Boiler Furnace Construction

WITH THE increasing use of powdered coal, combustion engineers a few years ago began to realize the need of some means of protecting furnace walls. At first the combustion space provided was so small that the flames impinged directly on the walls. Furnace maintenance was excessive, and in order to overcome the difficulty, combustion engineers started building large furnaces to keep the walls away from the flame.

There was, and still is, a false impression held by a few, that the large combustion space provided in the furnaces until a few years ago was for the primary purpose of getting better mixing of the gases. It has been found, however, that 1 cu. ft. of furnace volume, for each 20,000 to 24,000 B.t.u. liberated, is ample if the walls are made of such material or so designed that direct impingement of flame is unharmful. In some cases for both powdered coal and stokers it was necessary to increase furnace volume to somewhat larger proportions than formerly but not primarily, for combustion efficiency, to the marked extent found in units built 4 or 5 yr. ago, or longer.

THIS TABLE SHOWS DATA ON SUCCESSIVE BOILER INSTALLATIONS AT HELL GATE SINCE 1921

Year	1921-22	1923-24	1924-25	1925-26
Boilers				
Number	12	3	3	3
Tubes wide	54	54	54	54
Tubes high	20	16	12	12
Surface, sq. ft.	18,900	15,500	12,100	12,100
Water-cooled side walls				
Surface, sq. ft.	0	400	460	460
Superheaters				
Surface, sq. ft.	2,135	7,410	10,450	4,000
Location	Interdeck	Top of 1st Pass		
Economizers				
Surface, sq. ft.	0	13,824	12,100	10,692
Stokers				
Number per boiler	2	1	1	1
Retorts per stoker	14	14	14	14
Tuyeres long	17	33	33	33
Grate area, sq. ft.	472	378	378	378
Furnace volume, cu. ft.	8,000	6,500	6,500	6,500
Ratio of total water heating surface to grate area	40	42.1	32.3	33.3
Ratio of furnace to total water heating surface	0.423	0.41	0.517	0.517
Ratio of furnace volume to projected grate area	16.9	17.2	17.2	17.2
Ratio of superheating surface to total water-heating surface	0.113	0.478	0.466	0.317
Ratio of economizer surface to total water-heating surface	0	0.893	0.87	0.85

Although powdered coal probably can be burned efficiently with less excess air than with stoker firing, the latter method has made rapid progress and today we find coal being burned on all types of stokers with a minimum of excess air. This causes high furnace temperature which in turn causes fusion of ash and erosion of furnace lining. Besides this there is difficulty in removing fused ash from the furnace. In powdered coal installations the ash is sprayed in a molten state on the walls and bottom of the furnace; with stokers it is blown on the side walls and bridge wall and then fused into large masses of clinker.

Water-cooled Walls Reduce Maintenance Costs

To overcome these difficulties, engineers at first built enormous furnaces merely to keep the walls away from the flame and not primarily to develop high rating since the load scarcely ever exceeded an average of 225 per cent of rating. Now, in some cases by air-cooling of the side walls or more often by water-cooled walls, and in some cases, water-cooled arches, maintenance has been greatly reduced. An excellent example of the savings effected by modern furnace construction is shown in a paper presented by H. W. Leitch at a recent A. S. M. E. meeting in Providence, R. I.

As shown in the table, Mr. Leitch gives data on successive boiler installations at Hell Gate from 1921 to date. It is interesting to note that although the combustion volume has increased slightly, 5.17 cu. ft. per rated hp. now being used as compared to 4.1 in 1923, the average boiler rating as shown in Fig. 1, has increased in a greater degree than the furnace volume and has climbed steadily upward from 200 per cent in 1923 to above 250 per cent in 1925. Boiler efficiency also has increased, so that in proportion to the amount of coal burned to produce the higher ratings, the furnace volumes for the recent installations really are smaller than those of a few years ago.

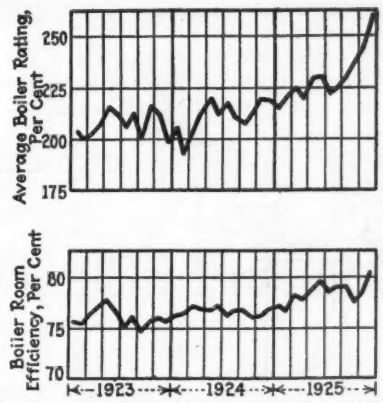


FIG. 1. UPPER CURVE SHOWS INCREASE IN AVERAGE BOILER RATING AT HELL GATE SINCE 1923. LOWER CURVE SHOWS INCREASE IN BOILER ROOM EFFICIENCY

Besides being one of the contributing factors in increasing efficiency and the average rating, Mr. Leitch states that water-cooled walls have reduced brick-work maintenance 54 per cent. In Fig. 2 is shown a side elevation of one of the stoker-fired furnaces with water-cooled walls responsible for this remarkable savings at Hell Gate.

Power plant engineers often are misled into believing that since their brick-work repairs are small they are not justified in installing air or water-cooled walls. In these cases, it generally will be found that a large capital expenditure has been made in order to operate boilers at low rating in order to save brick-work, or that combustion efficiency is not what it should be.

Air-cooled Walls Give Good Results

If preheated air is not used, air-cooled walls similar to the design shown in Fig. 3 may be used to advantage. With preheated air, however, the refractories in the hollow walls, in many instances, give trouble, especially with stoker firing. Hollow walls made of refracting material have been quite a step forward but these

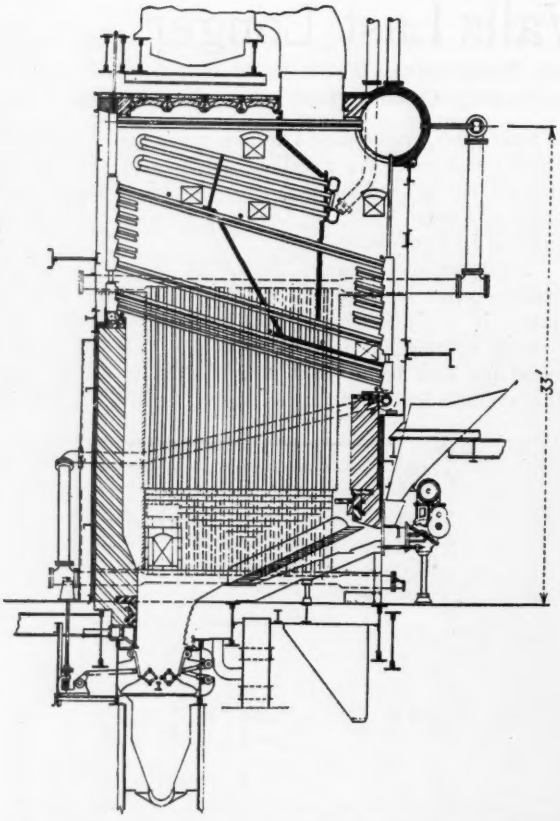


FIG. 2. WATER-COOLED WALLS HAVE REDUCED THE MAINTENANCE OF THIS STOKER-FIRED UNIT AT HELL GATE, 54 PER CENT

walls generally have been found more practical with powdered coal or oil firing than with stokers. This is due to the fact that in oil or powdered coal firing, air infiltration is not so extremely detrimental as in stoker firing and that in the latter, if the inner lining of the hollow walls is made sufficiently thin, so that the air-cooling is effective on the refractories, then the necessity of slicing off clinker or the abrasive action of the moving fuel takes away the wall as quickly as the extreme temperature conditions without cooling would affect a solid wall.

In stoker-fired installations, where only moderate ratings are expected and there is pronounced trouble only with clinker formation on the walls just above the surface of the fuel bed, the difficulty has been overcome by hollow, air-cooled blocks, either of carborundum

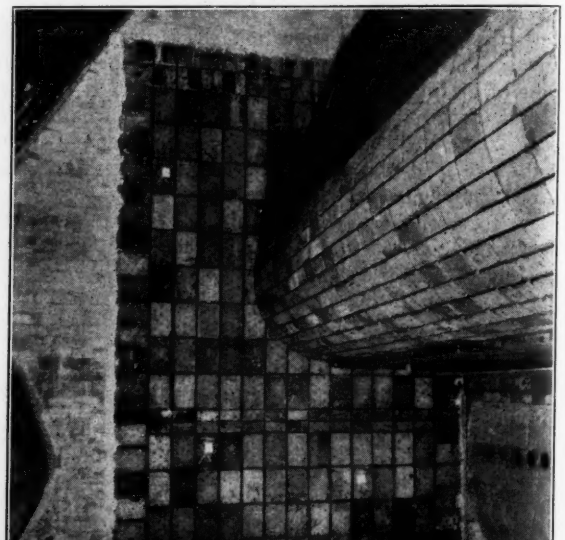


FIG. 4. WATER-COOLED WALL AND ARCH CONSTRUCTION HAS REDUCED THE MAINTENANCE ON THIS FURNACE TO A MINIMUM

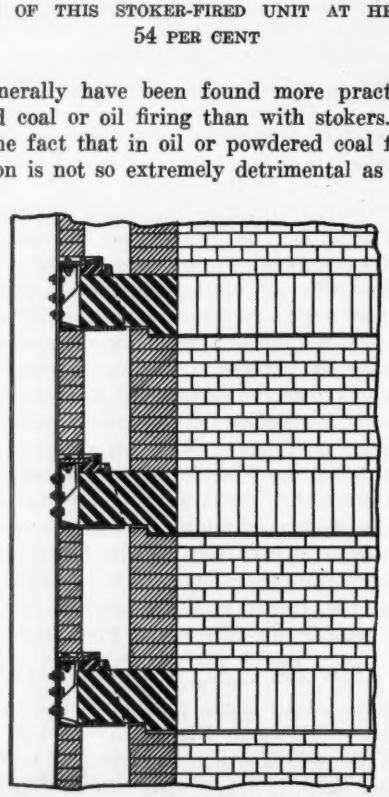


FIG. 3. THIS IS A REPRESENTATIVE TYPE OF AIR-COOLED WALL CONSTRUCTION

or some other high fusion-point material, with the air discharged into the furnace through perforations in the blocks.

New Design of Water-cooled Walls Has Refractory Surface

At the Western United Gas and Electric Co. at Aurora, Ill., there is one of the latest developments in water-cooled furnace construction, being a design having both water-cooled arches and walls. The surfaces exposed to the heat consist of cast-iron blocks having a refractory facing and are clamped tightly to tubes which are connected into the main circulatory system of the boiler. This refractory facing on the blocks permits operation with a furnace temperature high enough for efficient combustion while at the same time, the water-cooling holds down the temperature within safe limits. Construction is such that the wall is air tight and the kind of refractory, as well as the thickness, can be varied as required in different parts of the furnace or for dif-

ferent fuels, so as to give the desired furnace temperature.

In Fig. 4 is shown a water-cooled wall and arch construction for a traveling grate stoker installation under a bent tube type of boiler at the plant previously mentioned. Note the greater thickness of the refractory blocks at the front of the arch than on the curved portion. This is done to maintain a higher temperature for ignition purposes.

Figure 5 shows the rear of the tubes in one of the side walls before the insulating material was applied. This insulating material can be applied to the outer surface in a form of a plaster, to fill into the recesses of the clamps between and over the tubes. Even with the refractory on the inside of the furnace and this plaster on the outside, the thickness of the wall is less than 7 in. This permits a substantial reduction in the building volume required per boiler horsepower. This figure illustrates the manner in which the cast-iron blocks with the refractory facing are clamped to the tubes. There also is shown one of the special inspection doors which replaces one of the 6-in. by 9-in. blocks in the furnace wall.

Besides reducing furnace maintenance, water-cooled walls, due to the added heating surface, materially increase boiler ratings in addition to the greater possibilities of heat absorption resulting from the higher furnace temperature.

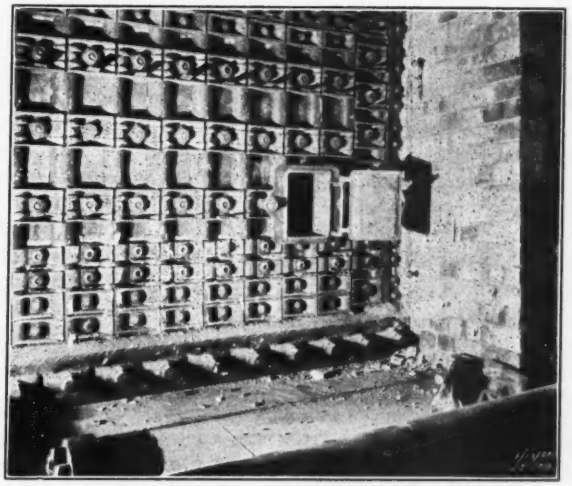


FIG. 5. THIS IS A REAR VIEW OF THE TUBES FORMING ONE OF THE SIDEWALLS AND SHOWS THE METHOD OF CLAMPING THE BLOCKS TO THE TUBES

Burners for Combination Gas-Oil Furnaces*

CONTINUOUS OPERATION MUST BE ENSURED AND QUICK CHANGE-OVER POSSIBLE WITHOUT LOSS OF LOAD. BY J. G. ROLLOW†

BURNERS and furnace arrangement which are satisfactory where gas and oil may have to be used alternately and the change made on short notice will also be satisfactory for the other two cases where either oil or gas is the major fuel and the other is used only at intervals or in case of breakdown.

In any case, so far as the furnace is concerned, one rightly proportioned and constructed for oil will function satisfactorily when using gas and it pays, whatever the conditions, to get the best possible equipment regardless of cost. Gain of a fraction of a per cent in boiler room efficiency or loss of the use of a boiler while making burner repairs, even if only for a short period, will more than offset any saving in the cost of burners.

Forms of burners and arrangement which have given good results are shown herewith. Figure 1 uses a steam atomizing burner for oil and has separate burners in individual openings for the gas and for the oil. Switch

*From a paper before the San Francisco Meeting A. S. M. E.

†Electrical Engineer, Los Angeles Gas & Elec. Corp.

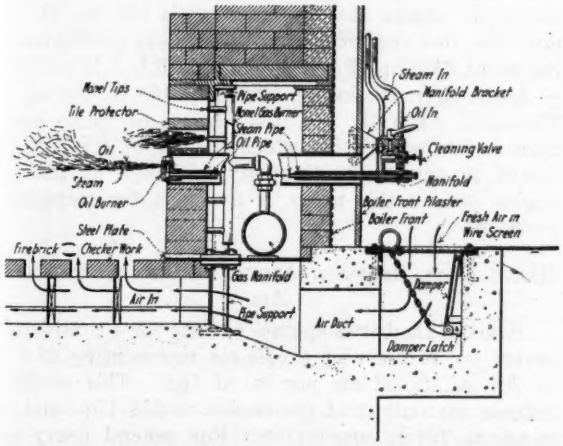


FIG. 1. GAS OR OIL CAN BE USED BY SIMPLY CHANGING THE SUPPLY VALVES

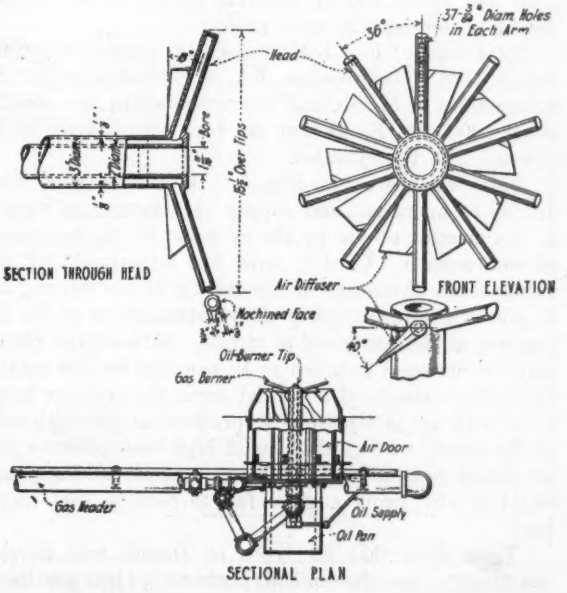


FIG. 2. DIFFUSER VANES ON THE GAS BURNER PREVENT PULSATION

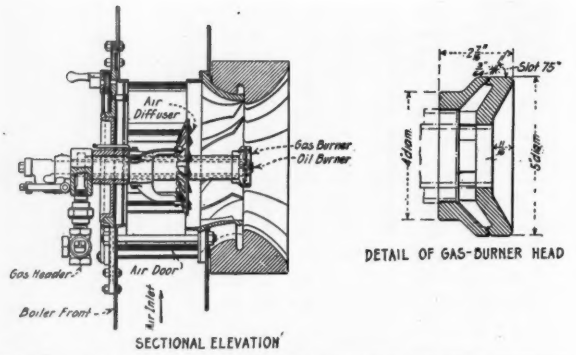


FIG. 3. OIL IS ATOMIZED MECHANICALLY IN THIS BURNER

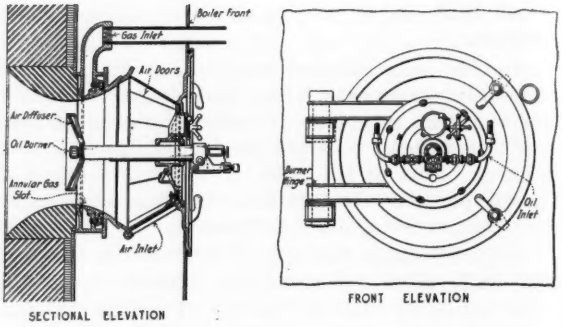


FIG. 4. THIS COMBINATION BURNER CAN BE SWUNG BACK FROM THE BOILER FOR CLEANING AND REPAIRS

can readily be made from one fuel to the other and maintenance is low for loads not over 150 per cent of rating with oil and 250 per cent with gas.

In 1922 the Babcock & Wilcox Co. introduced a combination burner for gas and mechanically-atomized oil, which was later developed as shown in Fig. 2. Diffusers welded to the gas burner arms stopped pulsation of flame and change to oil can be made by withdrawing the gas burner on a double-swing joint which also rotates the burner so that the arms and diffusers maintain their relative positions with the spiral blades of the oil-burner cone. Each burner, which costs ready to connect $120, will develop 450 b.hp. at a gas pressure of 10 lb. at the burner.

Figure 3 is a burner used at the Long Beach plant, also made by the Babcock & Wilcox Co. Oil is mechanically atomized and change-over from gas to oil is made by moving the diffuser from the position shown for gas burning up over the gas burner head. The burner carries 300 per cent of rating continuously with either fuel.

A combination gas and mechanically-atomizing oil burner, made by the Peabody Engineering Corp., is in use at Long Beach, Seal Beach, Los Angeles and Pasadena. It is of interest that pulverized coal has also been burned with this equipment.

Diesel Engine Rating Influenced by Design

INDICATOR CARD ANALYSIS SHOWS SAFE LOAD DEPENDS UPON TYPE, SIZE AND SPEED. BY J. J. MCDOUGALL

DIESEL engines of four general types are in common use and a study of their characteristics, by use of the indicator, will show why engines of the same dimensions and speed, but of different types, cannot be expected to develop the same power.

Solid lines of Fig. 1-A represent a typical four-cycle engine card. Compression, FA, is carried to about 35 atmospheres or 515 lb. and the temperature increases to about 1000 deg. F., so that the fuel ignites upon being injected into the cylinder.

Low pressure cards, Fig. 1-C, D and E, show conditions of operation and supply information in regard to the amount of air in the cylinder at the beginning of compression. Card C with fine adjustment of the valves takes advantage of the inertia of the moving air to give a pressure slightly above atmosphere at the beginning of the compression stroke. Safe engine rating may be increased as much as 10 per cent by this means. Card D is considered a normal card, the cylinder being filled with air at atmospheric pressure at the beginning of the stroke, while Card E with high back pressure and air intake resistance shows low volumetric efficiency and explains why many engines fail to develop their rated load.

Tests show that all types of Diesels will develop practically (not theoretically) about 3 i.hp. per lb. of fuel properly burned. Average fuel oils require about 14.5 lb. of air for theoretical combustion while the best value of excess air runs around 20 per cent. Under these conditions, 17.4 lb. of air will be required with each pound of oil. Due to mixing with the hot exhaust gases in the clearance volumes and contact with heated parts, the incoming air is heated to at least 100 deg. F., so that 17.4 lb. occupies a volume of about 245 cu. ft.

Assuming an engine of, say, 20 in. bore and 24 in. stroke running at 200 r.p.m., it is possible to calculate what may be expected under various conditions. In the four-cycle engine the displacement is 436 cu. ft. per min., the fuel requirement of 107 lb. per hr. representing about 320 i.hp. From the formula $P L A N \div 33{,}000 =$ horsepower, the i.m.e.p. would be 168 lb. per sq. in. The card, AB″C″D Fig. 1-A, drawn for these conditions is far beyond that which the engine could be expected to develop continuously, although in the best engine designs this m.e.p. is available for momentary overload.

HEAVY DUTY REQUIRES ABOUT 100 PER CENT EXCESS AIR

Some of the better engines operate for a considerable period on 50 per cent excess air representing 21.8 lb. or 307 cu. ft. of air per lb. of fuel. This condition reduces the output of the engine to 256 i.hp. and the m.e.p. to 134 lb. per sq. in. For general heavy continuous duty, however, an excess air of 100 per cent should be allowed, increasing the air requirements to 29

lb. or 409 cu. ft. per lb. of fuel. Under this rating, the power output of the engine would be 192 i.hp. with an m.e.p. of 100.5 lb. Engines rated at this m.e.p. may not always come up to full load, generally due to some condition as in Card E, or from leaky pistons or valves.

Although the i.m.e.p. is important, it is the b.m.e.p. or brake mean effective pressure which gives the actual power delivery of the engine. This value depends upon the friction horsepower or mechanical efficiency of the engine and must be known to give complete information. Mechanical efficiencies of the four-cycle engine vary from 75 to 78 per cent, so that the engine under discussion with 100 per cent excess air and an efficiency of 78 per cent would have a brake horsepower rating of 150 hp., a fuel consumption of 0.425 per b.hp.hr. and a thermal efficiency of about 31 per cent.

Power Stroke Is Shortened in Two-Cycle Engine

Two-cycle engines differ in the method of scavenging and charging the cylinders, Fig. 1-B being the normal card from a type using air valves in the head for this purpose. Air at about 4 lb. is generally supplied by an air pump driven from the engine. Air is not cooled after compression and the temperature of about 120 deg. F. is further increased to about 160 deg. upon reaching the cylinder. The first part of the cycle is similar to the four-cycle engine but at C the piston uncovers exhaust ports in the cylinder similar to the action of the uniflow steam engine. The pressure drops almost immediately to atmosphere, or below, reducing the effective working stroke usually by about 20 per cent. At M the air or scavenging valves open and the entering air clears the cylinder of burned gases. Practically the pressure at F is slightly below that of the compressor, averaging about 3 lb.

Considering the same engine as before, a 20 by 24 in. running at 200 r.p.m., the effective stroke has been reduced to 80 per cent or 1.6 ft. but the effective piston displacement increases to 700 cu. ft. per min. Heat stresses are greater than in the four-cycle engine but for practical purposes, the same excess air conditions may be assumed to hold true. High, or overload, ratings will have the same relative effect on both types so only normal operation of the two-cycle will be considered. Under normal conditions of 100 per cent excess air at 160 deg. F. and 3 lb. gage, 377 cu. ft. of air will be necessary for each lb. of fuel. The engine will then burn 111 lb. of oil per hr., developing 334 i.hp. at an i.m.e.p. of 109.5 lb. per sq. in.

Engines Should Be Rated on the Effective Stroke

Conditions over the effective stroke are slightly more severe than in the four-cycle engine but when referred to the actual stroke, the m.e.p. reduces to 109.5×0.80 or 87.5 lb. per sq. in. This rating is commonly used but, unless the effective stroke is known, has little meaning and is likely to be misinterpreted by a man familiar only with the four-cycle type. For purposes of comparison, two-cycle engines should always be rated on the effective stroke.

Seventy per cent is a fair mechanical efficiency for these engines, due to the high friction load caused by the scavenging air pump. On this basis the b.m.e.p. of the above machine is 61.3 lb. per sq. in., giving a brake horsepower of 234 and a fuel consumption of 0.475 lb. per b.hp.-hr. Due to the shortened stroke, a two-cycle engine of the same dimensions and speed will not deliver twice the power of the four-cycle engine unless it be run at a rating considerably in excess of that considered safe practice on the four-cycle type. It takes a good engine to develop the above i.m.e.p. of 87.5 lb. referred to the entire stroke.

Another two-cycle engine with cylinder ports instead of valves in the head for scavenging purposes gives

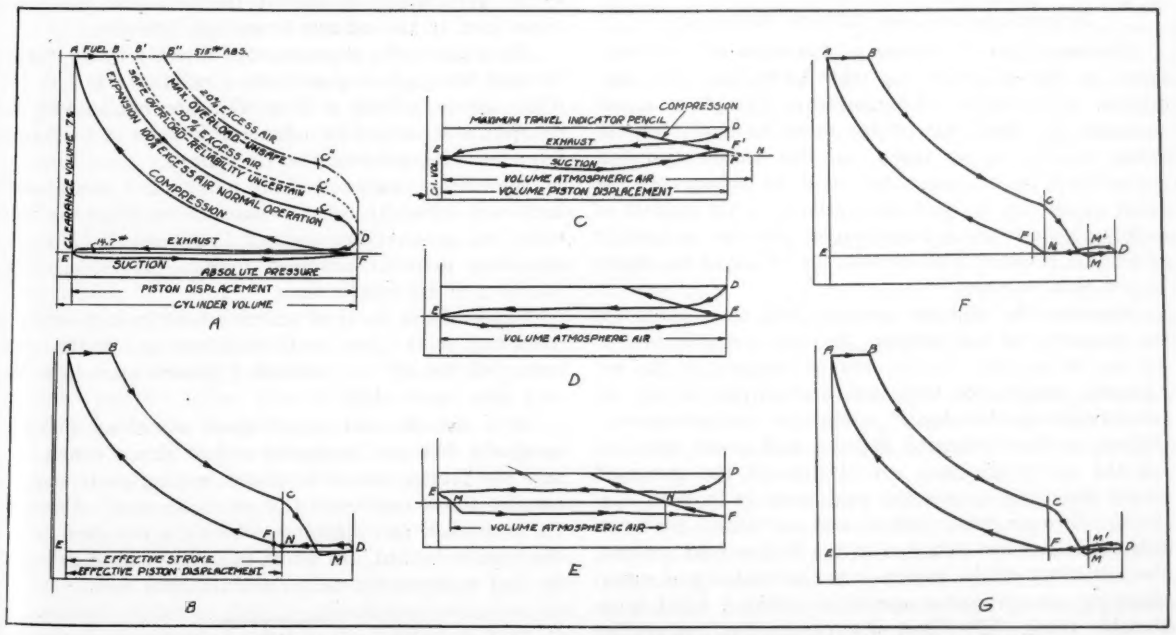


FIG 1. TYPICAL CARDS FROM VARIOUS TYPES OF ENGINES SHOW CHANGED CONDITIONS

A. Four-stroke cycle Diesel. B. Two-stroke cycle Diesel with scavenging valves in the head. C, D and E. Low-pressure cards from a four-stroke cycle Diesel. F. Two-stroke cycle Diesel with ports for scavenging and additional ports for supercharging. G. Two-stroke cycle Diesel with simple ports.

practically the same card, Fig. 1-F, and rating. On the down stroke of the piston, the exhaust ports are first uncovered, followed by the scavenging air ports. On the return stroke, after the exhaust valves close, additional air ports fill the cylinder with air at about 3 lb. pressure, giving the same conditions as in Fig. 1-B at the beginning of the compression stroke.

A third type of two-cycle engine, Fig. 1-G, uses only two sets of ports, so that the pressure in the cylinder, when the exhaust ports are closed, is atmospheric and a cylinder volume of 452 cu. ft. of air is required for each pound of fuel. As in the other two-cycle engines, displacement is 700 cu. ft. per min. and 92.5 lb. of fuel will be burned per hr. The output of 278 i.hp. gives an i.m.e.p. of 91 over the effective stroke or 72.7 lb. for the entire stroke. Mechanical efficiencies of these engines average about 65 per cent, reducing the output to 181 b.hp. and the b.m.e.p. to 47.2 over the entire stroke. Fuel consumption runs about 51 lb. per b.hp.hr. The output is but slightly higher than that of the four-cycle engine.

COMPARATIVE DATA ON FOUR TYPES OF ENGINES OF THE SAME SIZE SHOWS WIDE VARIATION

	FOUR STROKE CYCLE	TWO STROKE CYCLE		
		VALVES IN THE CYLINDER HEAD FOR SCAVENGING AND CHARGING CYLINDER WITH AIR UNDER PRESSURE	PORTS FOR SCAVENGING AND PORTS FOR CHARGING CYLINDER AFTER EXHAUST PORTS CLOSE	SIMPLE PORT SCAVENGING
I.H.P.	192	334	334	278
I.M.E.P. REFERRED TO EFFECTIVE STROKE	100.5	109.5	109.5	91
I.M.E.P. REFERRED TO ENTIRE STROKE	100.5	87.5	87.5	72.7
B.H.P.	150	234	234	181
B.M.E.P. REFERRED TO EFFECTIVE STROKE	78	76.6	76.6	61.8
B.M.E.P. REFERRED TO ENTIRE STROKE	78	61.3	61.3	47.2
MECHANICAL EFFICIENCY	78	70	70	65
FUEL CONSUMPTION POUNDS PER B.H.P.	.425	.475	.475	.51
THERMAL EFFICIENCY OVERALL	.31	.29	.29	.27
ALL ENGINES 20" BORE 24" STROKE, RUNNING AT 200 R.P.M. INLET AIR 14.7 ABS. AND 60°F				

Supercharging Not Always Advisable

Various types of engines of the same size are compared in the accompanying table under sea level conditions. If conditions of temperature, altitude or supercharging are used, corrections must be made for the actual weight of air taken into the engine cylinder. Super-charging is sometimes used to counteract the effect of altitude to pull an overload. This consists of supplying air to the cylinder under pressure as a slight additional pressure will increase the rating of an engine 10 per cent or more.

Knowing the absolute pressure and temperature at the beginning of compression, the expected gain in output can be figured. As the ratio of compression has not changed, compression increases to about 620 lb. and the temperature to 1100 deg. F., giving two undesirable conditions, so that increased friction and power required for the air pump may entirely absorb the increased power developed unless the equipment is in good condition. Proper valve setting and air pump condition helps considerably but, due to the higher heat stresses, the reliability of the engine is not increased and supercharging, except under special conditions, is of questionable value. The effect of supercharging, overrating or overloading depends upon the design of the engine, the material it is made of and the condition in which it is maintained.

Diesel Power Used on Pipe Lines

SINCE 1916, most of the power for pumping oil through pipe lines has been furnished by Diesel engines, although many old steam-driven plants are yet in use. In first cost, reliability and operating cost, the two methods may be considered as on practical equality. Fuel consumption per horsepower-hour is for the Diesel about one-third that for a steam-driven plant, and the maintenance cost is such that the Diesel plant shows a considerable superiority over the steam plant.

In a paper before the A. S. M. E. at San Francisco, Fred Thilenius made the above statements and gave some interesting data as to power required. Stations are about 40 mi. apart and units of 365 to 400 hp. are used for 20,000 bbl. a day capacity or 665 to 750 hp. for 40,000 bbl. capacity. Oil is pumped at 700 lb. pressure from a reservoir near the pumping station into one at the next succeeding station, about 15 hp. being required per 1000 bbl. pumped a day. The engine most in use in new plants is the 4-cylinder vertical with solid injection.

It is found good economy to use an engine at 1/8 to 1/6 below its rated capacity because of the severe service, fluctuating load and varying line pressure. A spare unit is provided as the ability to inspect, adjust and clean engines periodically and thoroughly cuts down maintenance cost. For midwest conditions, softening of the jacket water has been found to pay, also concrete open reservoirs of surface cooling type are a good investment.

Careful reclaiming of the bearing lubricating oil by means of centrifugal separators, chemical treatment and settling, are found to cut operating costs appreciably and to reduce wear on bearings.

To make sure that each cylinder is doing its share of work, pyrometers or special thermometers are sometimes used in the exhaust from each cylinder.

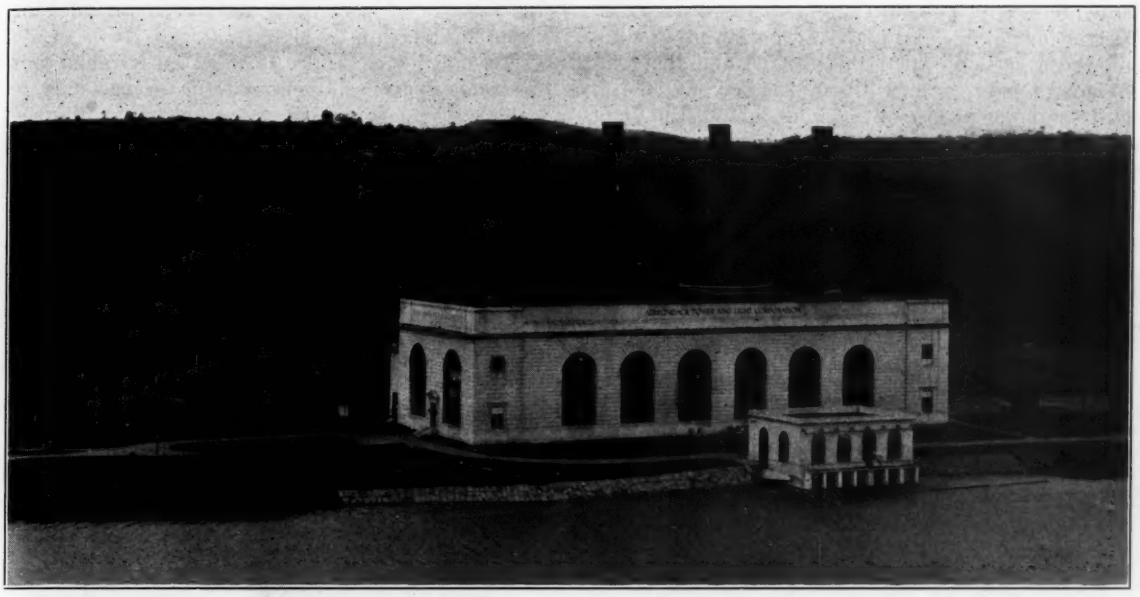
Main line units are connected directly to the pumps through herringbone gears with a ratio of 1 to 5 or 1 to 6, the pump running at 30 to 40 r.p.m. but engines and pumps are separated by a fire wall because of the hazard from broken connections on the pumps.

Generators, water and oil pumps and other auxiliaries are generally bolt or chain driven from the main units but an auxiliary unit of Diesel engine driving a generator is often provided to run the motor-driven pumps and air compressors.

Suggestion is made of utilizing heat from the exhaust gases but, so far, heating of buildings and of the lubricating oil during the reclaiming process seem to be the only uses made of it.

It is thought that use of shock absorbing chambers to steady flow and pressures and of thrust bearings to take the lateral strain on pump bearings may make it possible to use engines at full rated capacity. Also careful inspection and cleaning, which are reported on log sheets and checked, are found to improve average capacity and considerably reduce maintenance costs.

STEAM CYLINDER oil will furnish on an average over 6500 drops per pint. This will vary from 5000 to 8000 drops depending upon the viscosity.



Need Power Plant Structures Be Unattractive?

A Plea for Greater Attention to Architectural Beauty in the Design of Our Power Stations

ONE NIGHT, several weeks ago, as I was traveling from New York to Chicago on a New York Central train, shortly after leaving Albany and getting into my berth, I raised the shade and, as I often like to do before going to sleep in a Pullman, watched the countryside flash by through the night. We had just left Schenectady and the road was along the Mohawk River. Suddenly, the darkness was broken and there shot into view a dazzling white structure, beautiful in proportion and outlined against the darkness like a white-hot ingot. Below, the reflection of the floodlighted building lay inverted in the still waters of the Mohawk.

The effect was marvelous. That fairy-like white structure glowing against the dark sky must have impressed itself unforgettably on the minds of everyone that saw it. And to one, who for many years has been interested in power plant work, it is gratifying to know that this building was a power plant—the Amsterdam Power Station of the Adirondack Power and Light Corporation.

But power plants possessing such marked architectural beauty are rare; in fact, power plants with any attractive architectural features at all, however weak, are the exception rather than the rule.

The reason for this is not difficult to find. During the past 40 years the power plant industry has grown from nothing to perhaps the first industry in the land. It has progressed so rapidly that those engaged in it have been required to concentrate all their attention on the mechanical developments. As a consequence, architectural matters received scant attention. It was recognized, of course, that the expensive mechanical and electrical equipment needed to be protected from the weather and, to this end, walls and a roof were provided. But in most cases this was the limit of the architectural activity displayed. Ornamental considerations were scarcely ever given a thought and, if they were, only in an extremely superficial way. It is only within the past five years that any serious attempts have been made to produce power plant structures having architectural merit.

Another factor that perhaps is responsible for the absence of architectural beauty in American plants is the almost absolute influence of the engineer, over the design and construction of such structures. Where formerly one directing mind at once artist and constructor sufficed in the design and erection of building or bridge, today two minds are required. In most ordinary structures, the architect is still the director of the building, properly so-called, but the purely utilitarian construction, such work as is commonly believed to require no artistic treatment is entrusted to an engineer. The long education in art indispensable to the profession of the architect and the specialized technical training of the engineer which in the end permits every daring in the use of steel apparently cannot be held by one mind. While the architect and the engineer often collaborate, they more often ignore each other and, when this occurs, the work suffers.

Power stations are almost wholly mechanical and it is only natural that the requirements demanded by the engineer be satisfied completely without subordinating them to the demands of the architect. This, however, is no excuse for absolutely ignoring architectural beauty. The purpose of a power station is the economical generation of power from fuel and this purpose should be met in all cases but if, without sacrificing any of the utilitarian features, the structure can be made pleasing to the eye, even though the cost be increased somewhat, it should be done. Beauty has a definite place in our lives.

Of course, it may be argued that because power

plants are usually built in manufacturing districts, any effort or money spent in beautifying them would be lost. To a certain extent this is true and the writer does not propose to make Greek temples out of every industrial power plant. Yet, if in designing such plants, the element of architectural attractiveness always be kept in mind from the time the first layout is made until the finishing touches are put on the building, a structure can be produced which, while in no way costing much more than if attractiveness had not been considered, is, to use the vernacular of the day, decidedly easy to look at. Beauty in architecture does not necessarily mean great expense. Some of the world's most beautiful structures are amazingly simple and devoid of elaborate adornment. The Lincoln memorial is a typical example. What is more important than adornment is correctness of proportion and symmetry, both of which are attainable in a power plant structure.

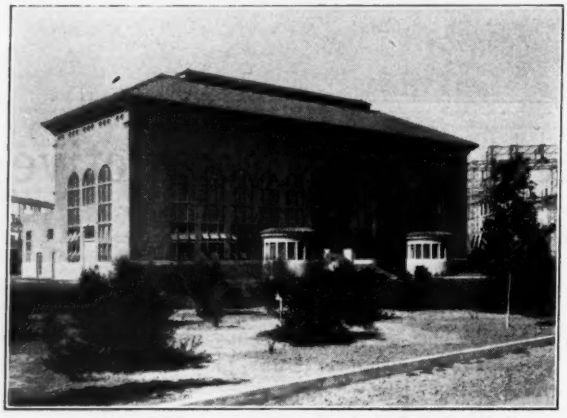


FIG. 1. THE BEAUTIFUL VACA SUBSTATION OF THE PACIFIC GAS AND ELECTRIC CO. THIS IS AN EXCELLENT EXAMPLE SHOWING WHAT CAN BE ACCOMPLISHED WITH CONCRETE

In the construction of a large central station, the question of architecture is of considerably more importance than in the construction of an industrial type of power plant. The central station is gradually assuming larger proportions and, like a great railroad station, is looked upon as an institution of public service. As such, a certain architectural dignity must be met which will give it the impressiveness required in public or semi-public buildings.

"But beauty has no value—it will bring no return on the investment!" That is an argument often advanced in defense of the unsightly structures which house our power-producing equipment. What value has beauty?

What value? What value has anything we covet and take pride in possessing because of its beauty? What value has a diamond which, after all, is nothing but a piece of crystal cut so as to reflect and refract the light in a pleasing manner? Of what value are the millions of dollars spent in the design and construction of Grand Central or the Pennsylvania railroad stations in New York City or the Union Station at Washington? Surely, the transportation facilities could be provided in structures of much less pretentious proportions and of far simpler design. Surely, there is no need for the great arched concourse at Grand Central. The same floor space could have been provided under a ceiling one-tenth as high.

To judge such works as the Pennsylvania railroad or Grand Central stations in terms of monetary value without seeing or feeling the grandeur, all the poetry, the inspiration which these great modern conceptions produce, is a form of intellectual cancer too pitiful to contemplate. Yet, if it must be measured in terms of dollars and cents, I am willing to wager that the millions spent in beautifying Grand Central have as much real earning power as a permanent advertisement as they would if invested in any other possible form of advertising.

In spite of the American's faith in advertising, the advertising value of beauty in architecture is something that has been consistently neglected. Our advertising bill is the highest of any country in the world. We spend millions upon millions of dollars annually in planting the countryside with chromatic eye-sores and in making our cities hideous with unsightly electric signs, yet the average business man would hesitate seriously before spending an extra fifty thousand dollars in beautifying a building which will stand as a dignified advertisement for his company for years to come. There have been, of course, some notable exceptions to this tendency to ignore the advertising power of good architecture. The new Tribune Tower in Chicago, the railway terminals already referred to, and others of a like nature are typical examples.

The Amsterdam station of the Adirondack Power Co., to which reference was made at the beginning of this article and which is shown in the headpiece, is a permanent advertisement of the highest value, which must impress the soundness of the company into the minds of the thousands that pass by on the railroad every day. This station, which has an ultimate capacity of 300,000 kw., is one of the most attractive steam-generating stations in America today. It is built of white cement mixed with marble chips, is symmetrical and extremely well proportioned. At night it is even more beautiful than during the day, as it is floodlighted by three banks of floodlights with a total load of 26 kw.

To build power stations attractively, however, it is not necessary to use the classic Greek form of design or to build them of white stone or marble. Some commendable work has been done with ordinary brick or with plain concrete. The building of the Vaca substation, shown in Fig. 1, is an excellent example of a concrete structure, well proportioned, artistic in appearance, yet not inordinately expensive. Substations, of course, lend themselves better to artistic treatment than do steam-generating stations because of the absence of stacks and because of their simpler layout.

In the early days of power station design the entire equipment, boiler, engine room and switching equipment was contained in one building usually with a dividing wall between the boiler and engine room. During recent years with the development of the turbine and high-tension switching equipment, the relative proportion of the boiler and engine rooms and the switch houses have changed considerably. This has resulted in a tendency to house each of these main divisions in a separate building and to design each building or room to fit the size of the equipment installed. This tendency is responsible for the broken, haphazard appearance of some

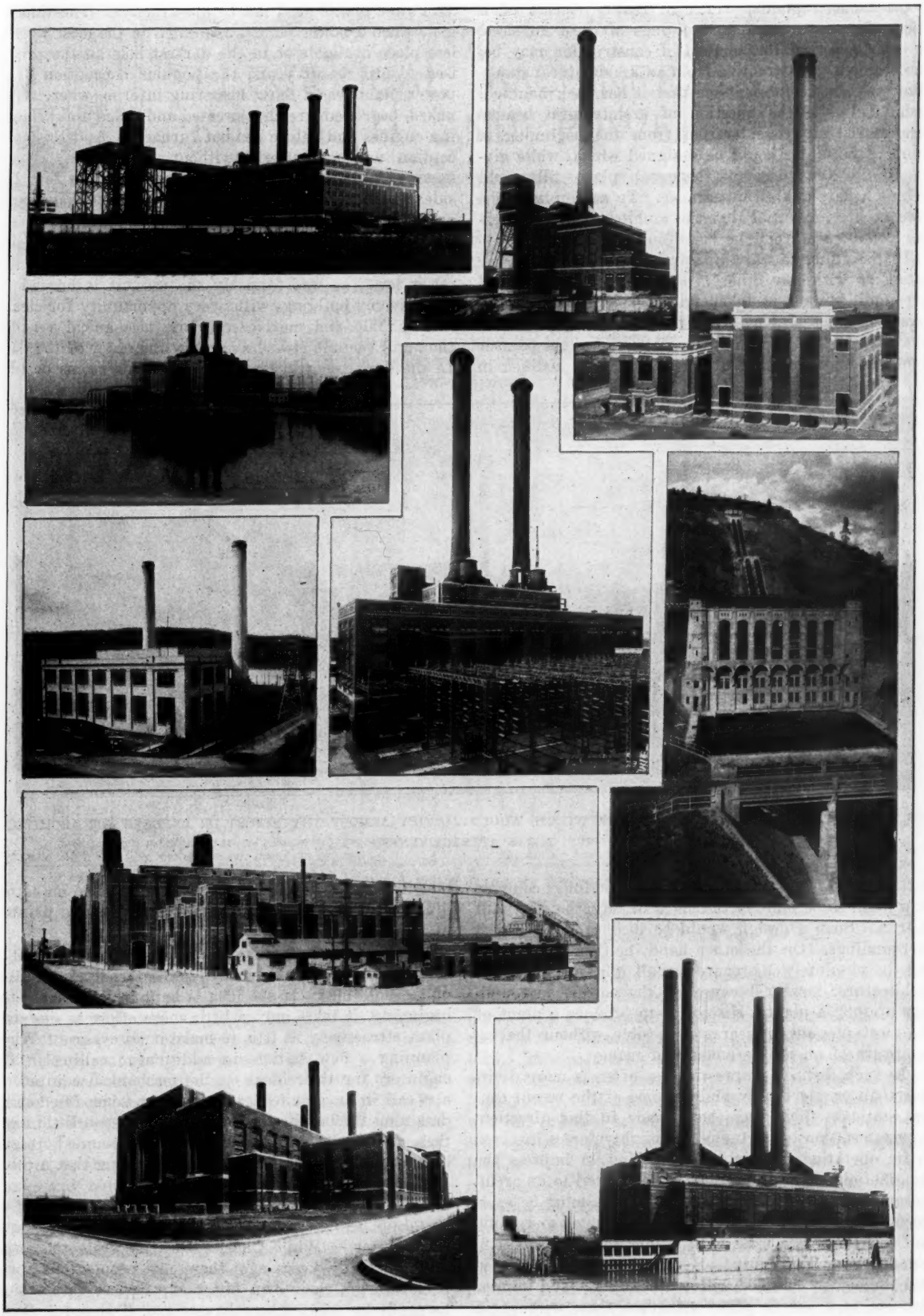


FIG. 2. A FEW TYPICAL EXAMPLES OF AMERICA'S POWER PLANTS OFFERED WITHOUT COMMENT. ARE THEY ATTRACTIVE OR NOT? DRAW YOUR OWN CONCLUSIONS

of the modern plants, which in reality consist of a group of variously shaped buildings of different sizes. However practical this method of construction may be, it is decidedly unattractive from an architectural standpoint, at least in the manner that it has been handled. Undoubtedly, if the question of architectural beauty were taken into consideration from the beginning, a group of buildings could be designed which, while giving all the advantages of the group plan, still would present a harmonious appearance. To accomplish this, however, it is essential that the architect and the engineer collaborate from the beginning.

In designing the architectural features of a power station as with any other type of structure, the local surroundings must be taken into consideration, for they have a distinct bearing upon the design of any structure. Regardless of how enthusiastic one might be over architectural beauty, no architect would be justified in putting a row of marble Corinthian or Ionic columns on a plant to be built in the midst of, say, the steel mill district. Such a design would be incongruous with its surroundings. On the other hand, neither is he justified in absolutely disregarding all the principles of architecture, merely because of the sordid surroundings of such a plant. His job is to produce a plant of the most pleasing appearance possible without the expenditure of an undue amount of money.

In such districts impressiveness often is more desirable than ornate beauty and in some of the recent central stations efforts have been made in this direction. A power station by virtue of the mighty forces involved in its operation, is essentially a thing to impress the imagination. Mass, therefore, is well suited to its architectural treatment. Great care, however, must be exercised in carrying out this idea, for it is much more difficult to incorporate mass with beauty than it is to combine grace with beauty. However, mass well placed and judiciously handled will confer dignity and impressiveness to a power plant structure that, without it, would be only another unsightly building which makes our industrial areas the God-forsaken places they are.

Power plants need not be unattractive. The time is gone when a power plant was located in the most worthless place available or in the darkest hole on the premises. Until recent years, the popular conception of a power plant was a dark, blistering inferno, where half-naked, begrimed wretches sweated and toiled amid clanking engines and before red-hot furnaces. And this conception was not utterly without foundation. There have been plants, and perhaps there still are a few, beside which the black hole of Calcutta would have been an attractive place.

Today, instead of locating the power-producing equipment in the subbasement three floors below the sewer level, as was formerly the case, it is housed in light, roomy buildings with every opportunity for cleanliness. Tile and marble interiors, mechanical ventilation, and vacuum cleaners are now the order of the day. In the larger central stations, the engine rooms or turbine halls, as they now are termed, have taken on cathedral-like proportions, and the boiler rooms are painted white!

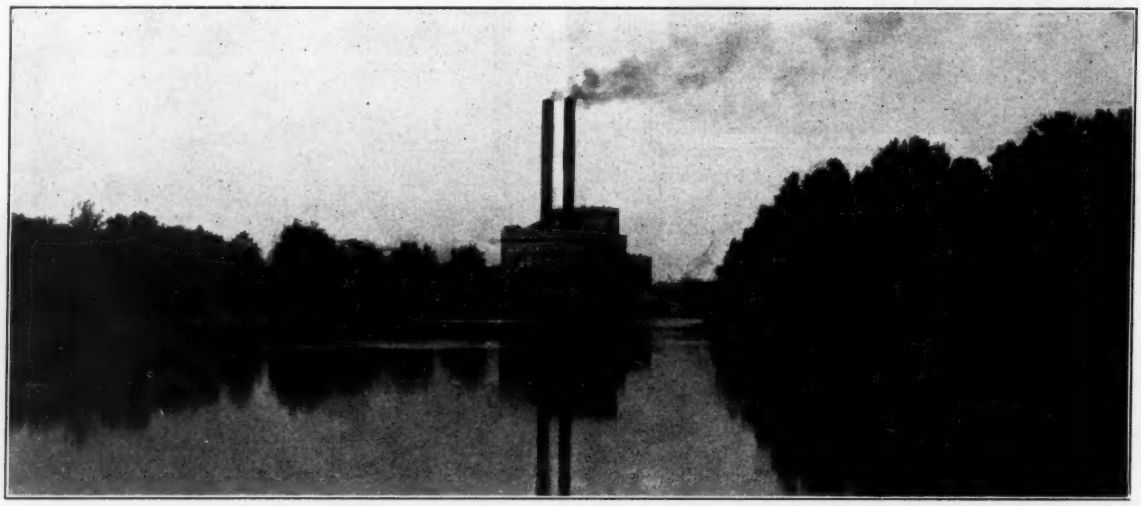
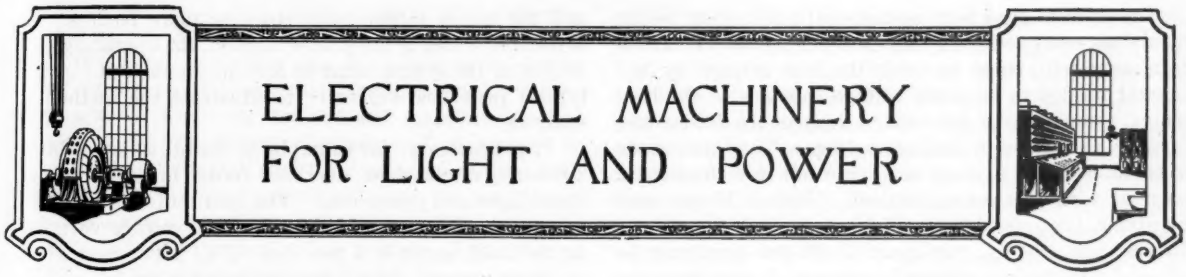


FIG. 3. A SETTING FOR A POWER PLANT WHICH WOULD JUSTIFY ALMOST ANY EFFORT OR EXPENSE FOR ARCHITECTURAL ATTRACTIVENESS

In view of these advances it is only fitting that a similar advance should mark the external appearance of the buildings. If the idea is kept in mind from the beginning, it takes only a little more effort to design a plant attractively as it is to make it an eyesore. When planning a new station, in addition to calling in the engineers for their ideas on the mechanical equipment, also call in an architect, and give him some freedom in designing the building. If his design costs a little more than four walls and a roof originally planned, it will be money well spent, for it is an old saying that a thing of beauty is a joy forever.

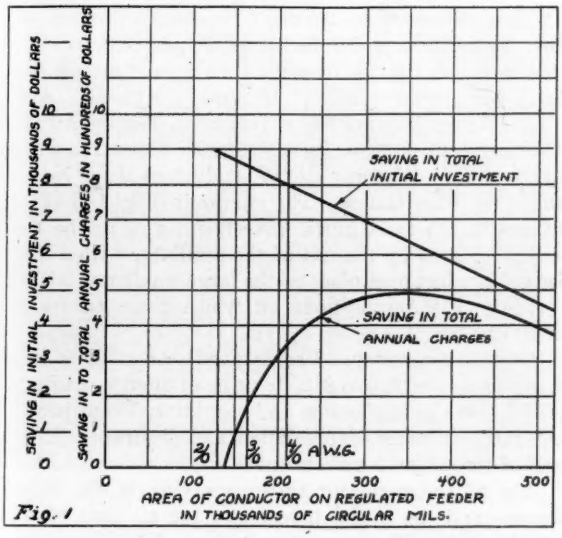
"LIVE AND LEARN, almost get killed and learn—and learn faster." While Charles Dickens wrote the above sentence many years ago, there are people today who prefer to get their own bitter experiences rather than to profit by what others have learned, observes David Van Schaack, vice-president of the National Safety Council.

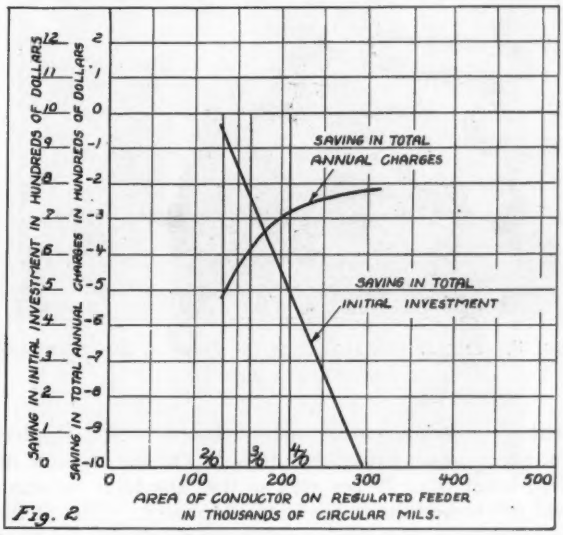


Voltage Regulators on A. C. Systems

IMPORTANCE OF REGULATING VOLTAGE, METHODS AVAILABLE, APPLICATION OF REGULATORS. BY M. M. EWELL*

REASONS FOR maintaining very close voltage regulation at the point of utilization of electrical energy on distribution systems are usually well known. However, to have them clearly in mind, some of the most important will be briefly reviewed.


SAVING IN INITIAL INVESTMENT IN THOUSANDS OF DOLLARS
SAVING IN TOTAL ANNUAL CHARGES IN HUNDREDS OF DOLLARS
SAVING IN TOTAL INITIAL INVESTMENT
SAVING IN TOTAL ANNUAL CHARGES
2/0 3/0 4/0 A.W.G.
0 100 200 300 400 500
AREA OF CONDUCTOR ON REGULATED FEEDER IN THOUSANDS OF CIRCULAR MILS.
Fig. 1


SAVING IN INITIAL INVESTMENT IN HUNDREDS OF DOLLARS
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SAVING IN TOTAL ANNUAL CHARGES
SAVING IN TOTAL INITIAL INVESTMENT
2/0 3/0 4/0
0 100 200 300 400 500
AREA OF CONDUCTOR ON REGULATED FEEDER IN THOUSANDS OF CIRCULAR MILS.
Fig. 2

FIG. 1 AND 2. SAVINGS MADE BY REGULATORS

Fig. 1. On a 2-mile, 200-amp., 2300-v. single-phase feeder with various sizes of conductors instead of 2-500,000-c.m. conductors required without regulator to limit load center regulation to 4 per cent. Fig. 2. On a 1-mile, 200-amp., 2300-v. single-phase feeder with various sizes of conductors instead of a 500,000 c.m. conductor required without regulator to limit load center regulation to 4 per cent.

The incandescent lamp is very sensitive to voltage changes and requires, for satisfactory operation, a voltage which is very close to that for which it was designed. Low voltage greatly decreases the illumination, while high voltage materially shortens its life.

The speed of alternating current motors is only slightly affected by a considerable change in the impressed voltage. The torque, however, varies as the square of the voltage, and unless the motor is liberally designed or considerably underloaded, a decrease in the voltage may reduce the starting or pull-out torque below the required value.

Many other applications, such as electro-chemical processes, electric furnaces and household heating devices, require close regulation for proper operation.

There are several methods of providing adequate voltage regulation, and the one which will prove most economical for a given set of operating conditions should be chosen, if all factors are the same. First cost, annual operating charges, allowable voltage variation at the load, and voltage variations on the feeder bus must all be considered in deciding upon the method to be used.

Among the various methods the first method conceived is to vary the bus voltage by the use of a regulator on the generator or an induction regulator on the bus to compensate for the line drop caused by any load. This is possible on a system where peak loads on all feeders come at the same time, and the variations of load on any feeder are not too severe. But this method will not produce satisfactory results on a typical modern system feeding a diversified power and lighting load.

The second method is to maintain the bus voltage constant and use a conductor of such size that the voltage drop in the feeder is within allowable limits when the maximum load is being carried. If the voltage at the bus is not constant the maximum drop in the feeder must be reduced to keep the total variation at the load within the prescribed limits. This method requires the use of a large conductor, which means that the first cost will be high.

*General Engineering Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

The third method is to use automatic induction feeder regulators equipped with line drop compensators. These regulators will boost or buck the bus voltage by the amount needed to keep the voltage constant at the load center, compensating for voltage drop in the feeder and for any variations in the bus voltage. They also make it possible to use a much smaller conductor than could be used with the second method. With a 10 per cent regulator, i. e., one which will boost or buck the voltage 10 per cent, a total variation of 20 per cent may be allowed. If the bus voltage is constant, it may be maintained 10 per cent above that desired at the load center. Then, at no load the regulator will buck the voltage 10 per cent and at full load it will boost the voltage 10 per

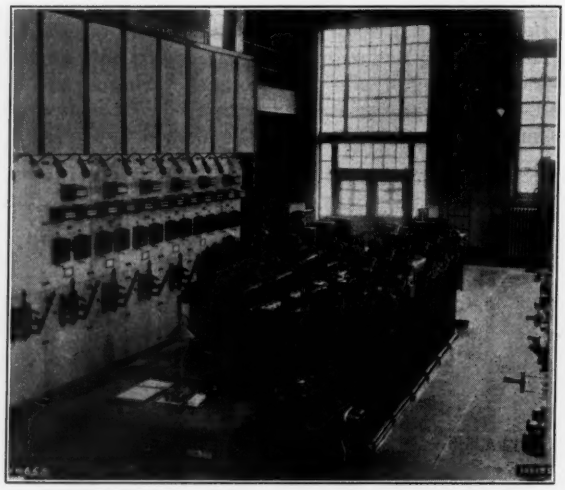


FIG. 3. SMALL INSTALLATION OF 46-KV.A. SINGLE-PHASE INDOOR REGULATORS

cent if the drop in the feeder requires it. If the bus voltage is not constant the drop in the feeder must be kept lower than 20 per cent so that the total variation will not exceed the range of the regulator. Thus, if the bus regulation is 5 per cent the drop in the feeder must be limited to 15 per cent, and the bus voltage must be so adjusted that its average value is 7.5 per cent higher than the load center voltage.

A fourth method is to decrease the line current, and consequently the voltage drop in the feeder, by changing to a higher primary voltage when loads on the feeders have reached a value where methods two and three no longer give satisfactory regulation. A change in the primary voltage means practically a re-design of the distribution system and the replacement or re-connection of the transformers, cables, switches, fuses and insulators. This involve a very large expenditure which must be justified by a careful analysis of existing conditions and the probable growth of the load. After the distribution voltage has been chosen, a decision must still be made between the use of regulators or conductors of such size that the regulation will not exceed the allowable limits. This is not, therefore, an independent method of securing regulation, but must be used in connection with one of the other methods.

When confronted with the problem the distribution engineer must usually choose between the use of induction feeder regulators with relatively small conductors and the use of larger conductors, or more feeders. To determine which is the proper method, the operating conditions of the system must be carefully analyzed. A few typical problems will serve to illustrate the method of analysis.

It is necessary, for example, to install a new 2300-v., 200-amp., single-phase, overhead feeder to supply a combined light and power load. The load center is two miles from the substation and the allowable voltage variation at the load center is 4 per cent, i. e., 2 per cent above or below normal. It will be assumed that the bus voltage is maintained absolutely constant. The average 24-hr. load curve for this combined light and power feeder will be approximately as follows:

1 hr. at 90 per cent of full load.
2 hr. at 80 per cent of full load.
3 hr. at 60 per cent of full load.
10 hr. at 50 per cent of full load.
2 hr. at 40 per cent of full load.
6 hr. at 20 per cent of full load.

To limit the voltage drop at full load to 4 per cent, it will be necessary to use two 500,000-c.m. lines in parallel, assuming a power factor of 88 per cent. Cost of the conductors for this feeder will be approximately $11,720, when copper wire cost 18 cents per pound. A 46-kv.a., single-phase induction regulator, having a range of 10 per cent boost or buck, will give closer regulation than is required for any size of conductors above No. 2/0 American Wire Gauge. The curves in Fig. 1 show the savings in the total initial investment and in the total annual charges by the use of the regulator with various sizes of conductor in place of the large conductor without a regulator. Assumptions on which these curves are based are:

Cost of conductor, 18 cents per lb.; cost of 46-kv.a., single-phase regulator, $1250; value of energy dissipated as I^2R losses in conductors and regulator, 1 cent per kw-hr.; interest, taxes, depreciation and insurance, 15 per cent of the original investment.

Use of the regulator shows a saving in the annual charges and the initial investment for all sizes of wire investigated. The regulator with a 350,000-c.m. conductor shows the lowest annual charges. As compared with the unregulated feeder, this arrangement saves nearly $500 per year in annual charges besides cutting the total initial investment in half.

The size of the conductor to be used will depend on the estimated growth of the load on the feeder, but there is no doubt that a regulator should be used, since it will save several thousand dollars in the first cost and several hundred dollars per year in the total feeder charges.

Conclusions for a short feeder are sometimes different than for a long feeder. Assume a feeder similar to the one in the preceding example, except that it is only one mile in length. The load curve, costs and required regulation will be assumed to be the same. Without a regulator, a single 500,000-c.m. conductor will be required, and its cost will be approximately $2930. Curves in Fig. 2 show the relation of the initial investment and the annual charges for the 500,000-c.m. feeder to the same values for smaller sizes of conductor with a 46-kv.a., single-phase regulator. The saving in the investment is perhaps not sufficient to justify the installation of a regulator on this feeder since the annual charges are considerably lower for the unregulated feeder.

However, the upper limit of the capacity of the unregulated feeder is 200 amp. with the allowable regulation, while the feeder using any size of conductor No. 3/0 or larger with a properly selected regulator will be able to carry a much larger current and still maintain constant voltage at the load center. Therefore, if an increase in the load is anticipated, the regulator and smaller conductor may prove more economical than the larger conductor without a regulator.

The next investigation will be a study of an existing 2300-v., single-phase, overhead feeder two miles long. A 500,000-c.m. conductor is used and the maximum load which can be carried with the allowable voltage drop of 4 per cent is 100 amp. It is desired to increase the capacity of the feeder to 200 amp. The load curve and costs will be assumed to be the same as in the first problem.

A single-phase 10 per cent regulator, rated at 46 kv.a., will increase the capacity of the existing feeder to more than the required value. The alternative is to install a new 500,000-c.m. feeder paralleling the existing one. If the conductor costs 18c per pound and the regulator costs $1250, the total investment in the two cases will be:

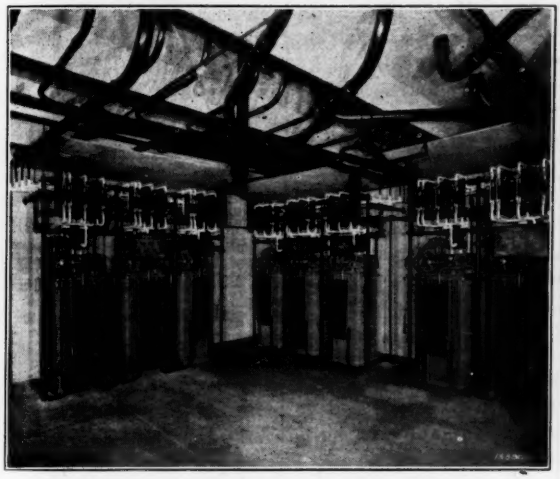


FIG. 4. 34.5-KV.A. SINGLE-PHASE INDOOR REGULATORS INSTALLED IN MODERN SUBSTATION

2—500,000-c.m. lines in parallel	$11,720
1—500,000-c.m. line and 46-kv.a. regulator	7,110
Saving on the investment by using regulator	$ 4,610

At 1 cent per kw-hr. for the I^2R losses and 15 per cent on the investment for fixed charges, a saving of $400 will be made in the annual charges by using the regulator. The above saving on the investment does not include the cost of insulators, line hardware and installation of the second feeder, nor value of the pole space which it will occupy. These will vary considerably with local conditions but will be a large item in favor of the regulator in any case.

One disadvantage of low voltage at the load, which is often discounted by operating companies, is that it decreases the amount of energy sold.[1] Another problem will illustrate this point.

A single-phase, 2300-v. lighting feeder has a capacity of 200 amp. The line drop to the center of distribution is 4 per cent during the daily 2-hr. period when full load is being carried. The lamps have a normal rating of 115 v., and this would be obtained at the lamps during the full load period if the voltage at the load center was normal. This voltage is, however, 4 per cent below normal, and so the lamps receive only 96 per cent of their rated voltage. The power used is 5.5 per cent less than it would have been with normal voltage, and in a year the decrease in energy consumption during the two-hour peak-load period will amount to 18,500 kw-hr. Assuming the retail value of electricity to be 9 cents per kw-hr., this represents a loss of $1650 per year which is directly due to low voltage. An automatic induction regulator which will maintain constant voltage at the load center at all loads will cost only $1250, and it will pay for itself and return a profit of 32 per cent on the investment in the first year. After that it will cost nothing and will increase the income of the central station by $1660 per year, or 130 per cent of the cost of the regulator. The loss of energy in the regulator has not been included since it will be more than balanced by the decrease in the sale of power due to low voltage during the hours of the day when less than full load is being carried.

FIG. 5. 46-KV.A. SINGLE-PHASE INDOOR REGULATORS INSTALLED IN MODERN SUBSTATION

BUS VOLTAGE VARIATION

In all of the above illustrations, the bus voltage has been assumed constant. This, however, is not the case on most systems, and variations in bus voltage up to 5 or 6 per cent are not uncommon. Regulation at the load center is equal to regulation at the bus plus the regulation due to line drop in the feeder. Thus, if the total

[1]This is an important point which many companies fail to take into account. There is a loss in revenue of $10.00 per hr. for each 10,000 residence customers whose socket voltage is five volts lower than the rating of lamps and appliances. These customers save 7 per cent of their bills but lose 15 per cent of their light.—Ed. Note.

variation at the bus is 3 per cent, and the allowable regulation at the load center is 4 per cent a drop of only 1 per cent may be allowed in the feeder at full load if a regulator is not used. However, with a 10 per cent regulator a line drop of 17 per cent may be allowed and still maintain constant voltage if the bus voltage is kept at an average of 8.5 per cent above that desired at the load center. It is evident from the calculations above that the investment will be excessive if the drop in the feeder is limited to 1 per cent. Moreover, if the bus voltage variation is 4 per cent or more, it will be impossible to maintain the required regulation regardless

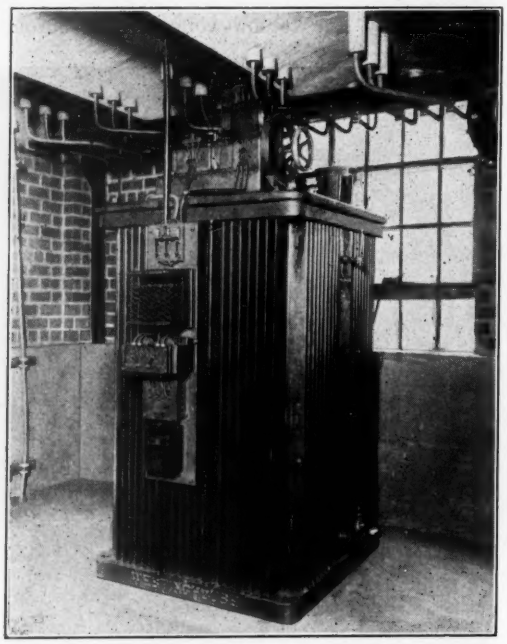


FIG. 6. 114-KV.A. THREE-PHASE FEEDER REGULATOR

of the size of the conductor used. In this case it will be necessary to use induction regulators on the feeders or to improve the regulation on the bus.

Automatic induction regulators will, in many cases, prove a source of income to the central station by decreasing the initial investment, reducing the total annual charges, and increasing the sale of energy by maintaining normal voltage at the utilization device as shown above. They will also improve the service to the consumer by compensating for variations in the bus voltage and the voltage drop in the feeder. Improved service means increased good-will, and while this may not have a cash value which appears on the ledger, it is something for which public service companies are constantly striving.

SELECTION OF REGULATORS

After it is decided to install induction regulators, it is necessary to use considerable care in the selection of the proper type to meet the specific conditions on the system. The indoor station type of regulator is cheaper than the outdoor type and where space is available in the substation this type is usually selected. Typical single-phase, indoor-type regulator installations illustrating the arrangements used by different companies are shown in Fig. 3, 4 and 5. Fig. 3 shows a station not originally designed for regulators in which the available space is very limited and the regulators are located in the center of the switchboard room with very little clearance between units. Figures 4 and 5 illustrate very modern installations in stations designed for regulators. Banks of three single-phase units are used on each three-phase circuit. The three regulators forming a bank are located close together but in both stations additional separation is provided between the units on different feeders. In Fig. 4 this separation is obtained by leaving more space between banks than between the units forming a bank. In Fig. 5 the banks are separated by concrete barriers.

A three-phase regulator, illustrated by Fig. 6, requires less space for a given capacity than three single-phase regulators, and may be used on three-phase circuits. A very much smaller space is required by a three-

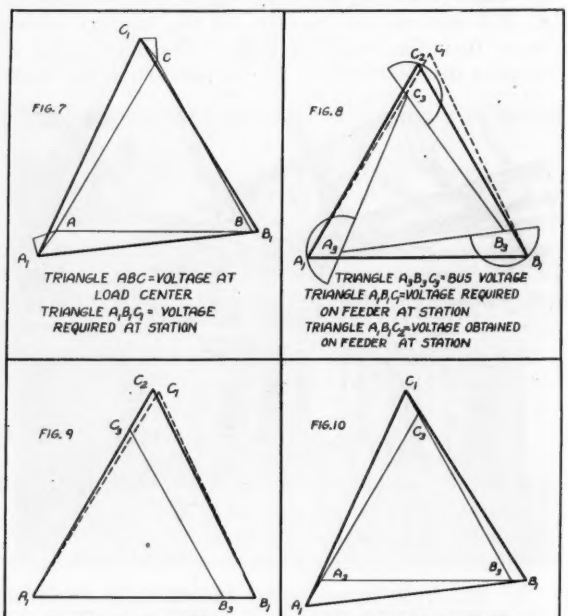


FIG. 7
TRIANGLE ABC = VOLTAGE AT LOAD CENTER
TRIANGLE $A_1B_1C_1$ = VOLTAGE REQUIRED AT STATION
FIG. 8
TRIANGLE $A_3B_3C_3$ = BUS VOLTAGE
TRIANGLE $A_1B_1C_1$ = VOLTAGE REQUIRED ON FEEDER AT STATION
TRIANGLE $A_1B_1C_2$ = VOLTAGE OBTAINED ON FEEDER AT STATION
FIG. 9
TRIANGLE $A_1B_3C_3$ = BUS VOLTAGE
TRIANGLE $A_1B_1C_1$ = VOLTAGE REQUIRED ON FEEDER AT STATION
TRIANGLE $A_1B_1C_2$ = VOLTAGE OBTAINED ON FEEDER AT STATION
FIG. 10
TRIANGLE $A_3B_3C_3$ = BUS VOLTAGE
TRIANGLE $A_1B_1C_1$ = VOLTAGE REQUIRED ON FEEDER AT STATION
TRIANGLE $A_1B_1C_2$ = VOLTAGE OBTAINED ON FEEDER AT STATION

FIG. 7-10. DIAGRAMS SHOWING METHODS OF SOLVING REGULATOR PROBLEMS

Fig. 7. Vector diagram for 3-phase feeder with unbalanced loads.
Fig. 8. Regulation of a 3-phase feeder with a 3-phase regulator.
Fig. 9. Regulation of a 3-phase feeder with 2 single-phase regulators.
Fig. 10. Regulation of 3-phase feeder with 3 single-phase regulators.

phase bus regulator, which may be used where loads on all phases are balanced and the load changes on all feeders are nearly equal and come at the same time. Or it may be used in connection with feeder regulators to compensate for voltage variations on the station bus. This arrangement makes it possible to use feeder regulators having a smaller range and may reduce the first cost of the station especially if some of the feeders are short and do not require regulation in addition to that furnished by the bus regulator.

If space is not available in the station, outdoor-type regulators may be used. They may be located just outside the station, at the center of distribution or at the

customer's plant. If they are located in either of the last two places, line drop compensators may be omitted.

It sometimes happens on a feeder supplying both light and power to an industrial plant that the power load does not require a regulated voltage. In this case the feeder may be split close to the load, and a regulator used in the branch supplying the lighting load. This will give efficient illumination with a much smaller regulator than would be required to regulate the voltage for the whole load. An outdoor regulator, or a pole-type regulator if the amount of the lighting load is small, is adaptable for this application.

If the feeder load is fairly well concentrated, regulators at the station will give very satisfactory regulation. However, if the feeder supplies a large area, considerable voltage variation may be found on the parts at some distance from the load center. In such cases, it is sometimes advisable to use pole-type regulators on the long branches of the feeder in addition to a regulator at the station.

For single-phase circuits single-phase regulators must be used, but on three-phase circuits two or three single-phase regulators or one three-phase regulator may be used. If the three-phase load is balanced at all times, any of these arrangements will be satisfactory.

Assume a feeder on which the station voltages on the three phases should be as shown in Fig. 7 by triangle $A_1B_1C_1$ in order to give the voltages forming the equilateral triangle ABC at the load center.

A three-phase regulator will change all voltages equally and simultaneously, and will give the voltage triangle $A_1B_1C_2$ in the vector diagram in Fig. 8. The position of the regulator will be determined by the voltage on the phase AB across which the primary relay is connected and by the currents in the two lines in which the current transformers for the line-drop compensator are connected. When the feeder supplies an unbalanced load, each phase requires a different amount of regulation, and it is evident that a three-phase regulator cannot give the correct voltage on all phases under these conditions. Two single-phase regulators will give the correct voltage on only two phases, as shown in Fig. 9. Voltages A_1B_1 and C_2A_1 have the required value, but the voltage B_1C_2 on the third phase cannot be independently adjusted, and is changed when either of the regulators operate. This arrangement will, in most cases, gives better regulation than one three-phase regulator. However, the correct voltage on all phases under all conditions of load can be obtained only by using three single-phase regulators, one of which is connected in each phase. Each of these regulators will adjust the voltage to meet the demands on one phase, regardless of the demands on the other phase, as shown by the vector diagram in Fig. 10. A change in the position of each regulator may be necessary when the load changes on only one phase, but the regulators will adjust themselves to give correct voltage on all phases for any degree of unbalance.

Economic Phases of Power Factor Correction

THE VALUE OF RECOVERED CAPACITY DUE TO POWER FACTOR CORRECTION DEPENDS UPON WHETHER IT CAN BE USED OR NOT. BY FRED C. DEWEESE

POWER FACTOR correction from an economic standpoint, is quite a different problem from what it is when considered from the engineering point of view, due to the fact that, when considered purely from the financial end, there are so many variables entering into the subject that no general rule can be made to apply. Each problem must usually be considered in accordance with the surrounding conditions and worked out as an individual problem of its own.

Some engineers put the thing in this way. "The most economical limit of power factor correction is reached when the operating cost of the condenser, plus the interest and depreciation on the first cost of the installation is equal to the value of the recovered station and line capacity."

The value of the recovered station and line capacity is a variable quantity. For instance, if none of the recovered capacity can be utilized, it will be an expense item, as there will be a certain amount of annual cost on the first cost of this recovered capacity. On the other hand, if there is a market for the recovered capacity, it may show a profit.

In the opinion of the writer the statement as to the economical limit of power factor correction should be stated as follows: "The economical limit of power factor correction is reached, when the sum of the annual cost of the condenser installation (fixed charges and operating cost) and the cost of delivering power to the load is a minimum."

When considering the installation of a condenser for power factor correction, every condition surrounding the proposed installation must be taken into consideration. Such as, whether the condenser is to be installed in a building being used to house other machinery, whether new buildings must be constructed, whether the condenser is to be operated in connection with other machinery, whether it is to carry any mechanical load, etc.

We will consider the case of a line, of an economic design for a 1000-kw. load, 50 mi. in length, 33 kv., 60 cycles, 3-phase, 80 per cent load power factor, mean annual load to be 65 per cent of full load, or, a continuous load of 650 kw.

The problem is to determine whether there will be any saving, and how much, by correcting the power factor to 95 per cent.

The condenser is to be installed in a building with, and operated in conjunction with other machinery and to have charged against it a proportional amount of labor. The above is the most usual case to be met with in general.

Voltage to neutral=33,000/1.73=19,075 v.

Kv.a. load=1000/0.8=1250 kv.a.

Kv.a. per conductor = 1250/3 = 416 kv.a.

Kw. per conductor = 1000/3 = 333 kw.

Current = 416,000/19,075 = 21.8 amp. per conductor.

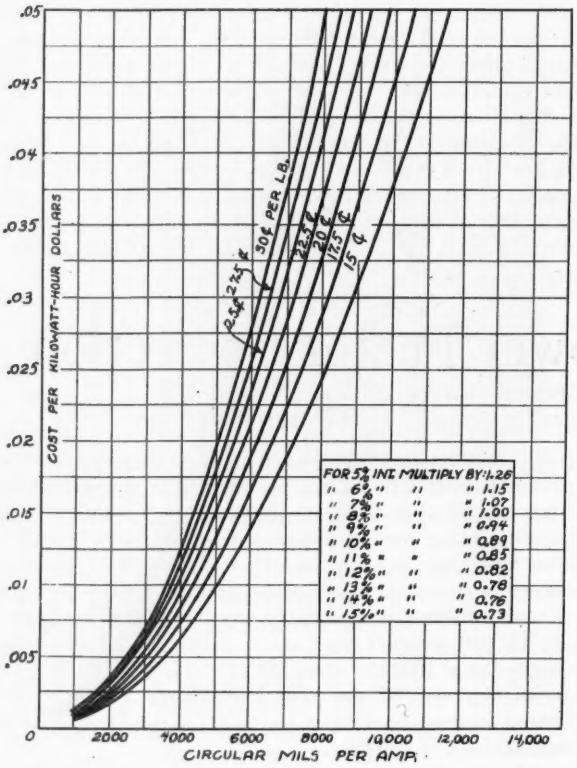
Mean annual current = $0.65 \times 21.8 = 14.2$ amp.

We will assume that the cost of generating plant and transmission line is \$150.00 per kw. The total cost will be $1000 \times 150 = \$150{,}000$. We will assume further,

that the annual fixed charges are 11 per cent. In this case, the annual fixed cost will be 0.11 × 150,000 = $16,500 per annum.

The power delivered at the end of the line is equal to 650 × 8760 = 5,942,000 kw-hr.. 16,500/5,942,000 = $0.00278 per kw-hr., fixed cost. We will assume that the fixed charges are 20 per cent of total cost. Then, 0.00278/0.20 = $0.0139 per kw-hr., total cost.

It is now necessary to determine the most economical size conductor to use, and this may be determined from the curves in the accompanying chart. For a cost of $0.0139 per kw-hr., project to the right to the 22.5 cent curve. (22.5 cents per pound is assumed to be the cost of the conductor, in place.) Thence vertically downward to the bottom of the sheet and it will be seen that the circular mils per amp. is approximately 4900. As these



CURVES FOR DETERMINING MOST ECONOMICAL SIZE OF COPPER

curves were constructed on a basis of 8 per cent, the factors in the lower right hand corner of the sheet are to be used for any other rate. It will be seen that the factor for 11 per cent is 0.85. 0.85 × 4900 = 4165 circular mils per ampere of the most economical size copper. 14.2 × 4165 = 59,200 circular mils total cross section of the conductor. The nearest size standard wire to this is No. 3 B. & S. gage.

The resistance of this wire is 1.1 ohms per mile. 50 × 1.1 = 55 ohms, total resistance. The I^2R losses are equal to $(14.2)^2 \times 55 \times 8760 \times .3$ = 291,500 kw-hr. per year. This is at 80 per cent power factor. The total cost is equal to (5,942,000 + 291,500) × 0.0139 = $86,645.

We will now see what the effect is upon the cost of delivering power after the power factor has been raised to 95 per cent.

This will require approximately 300 reactive kv.a. in condenser capacity. We will assume that the cost of condenser is $15.00 per kv.a. installed. 15 × 300 = $4500. The labor charges are to be $300 per year. The kilowatt input into the condenser is assumed to be 5 kw.

It was shown above that the losses were 291,400 kw-hr. at 80 per cent power factor. From the table, it will be seen that the factor for 80 per cent power factor is 1.56. The I^2R losses at 100 per cent will be 291,500/1.56 = 186,800 kw-hr. At 95 per cent power factor the loss will be 186,800 × 1.1 = 205,500. The condenser losses are 5 × 8760 = 43,800 kw-hr. 205,500 + 43,800 = 249,300 kw-hr. per year, at 95 per cent power factor. Total generated power equals 249,300 + 5,942,000 = 6,191,300 kw-hr.

The annual charge on the first cost of the condenser installation is 0.11 × 4500 = $495.00. Total annual fixed charges on invested capital equals 16,500 + 495 = 16,995. Total annual cost at 95 per cent power factor equals 6,191,300 × 0.0139 + 300 = $86,360. This is the total cost after power factor correction.

Before correction the cost is seen to be $86,645, which shows the net saving to be only 86,645 — 86,360 = $285.00. Thus it will be seen, that as a saving in dollars and cents it is just about an even break, not considering the recovered station and line capacity.

The amount to be earned by the recovered capacity will of course depend upon whether there is a market for it, the rate per kw-hr. for that which is sold, the power factor at which it is transmitted, etc.

TABLE FOR DETERMINING I^2R LOSSES AT VARIOUS POWER FACTORS

P.F.%	Factor	P.F.%	Factor	P.F.%	Factor
95	1.102	80	1.560	65	2.370
94	1.124	79	1.600	64	2.450
93	1.162	78	1.650	63	2.500
92	1.177	77	1.690	62	2.600
91	1.210	76	1.745	61	2.680
90	1.232	75	1.784	60	2.800
89	1.254	74	1.820	59	2.870
88	1.288	73	1.875	58	3.000
87	1.322	72	1.935	57	3.060
86	1.345	71	2.000	56	3.180
85	1.392	70	2.050	55	3.300
84	1.415	69	2.100	54	3.410
83	1.440	68	2.160	53	3.580
82	1.490	67	2.225	52	3.700
81	1.525	66	2.300	51	3.830

The accompanying table is composed of factors, which are the square of the reciprocal of the power factor. To use this table, first: determine the I^2R losses at 100 per cent power factor, after which it is only necessary to multiply by the factor corresponding to any other power factor for determining the losses at that power factor.

To use the curves for determining the most economical size copper, it is first necessary to determine the

mean annual current, which can be computed from the load curve, and then multiply the circular mils per amp., as determined from the curve, by the mean annual current.

The economic consideration of power factor correction is a problem that is becoming more important each day and deserves a lot of deep study from the engineers of the country. For instance the correction of power factor may prolong the time when it will either be necessary to add another circuit to a line, increase the size of the conductor, increase the transmission voltage or build another line altogether, in order to obtain more capacity. The increase in line capacity may be accomplished in several ways, but if the desired increase in capacity can be had by installing power factor corrective apparatus, this usually is the cheapest way.

Consumers Power Co. Adds Hodenpyl to System

CONDUIT SPILLWAYS, DUPLEX EXCITERS AND EARTH DAM WITH CONCRETE CORE WALL FORM SOME OF INTERESTING FEATURES OF NEW 25,000-HP. HYDRO PLANT. BY E. M. BURD*

ON THE MANISTEE RIVER, 25 mi. west of Cadillac, Michigan, Consumers Power Co. has recently completed Hodenpyl Dam. This 24,000-hp. plant is the second on the Manistee River, which, with six similar developments on the Au Sable River, are all connected by 140,000-v. transmission lines to the distribution area in the southern part of the state, stretching from Muskegon through Grand Rapids, Kalamazoo, Battle Creek, Jackson, Lansing, Saginaw, and Bay City. This system comprises 700 mi. of 140,000-v. line connecting the 34 hydro and 11 steam plants with 183 cities and towns served.

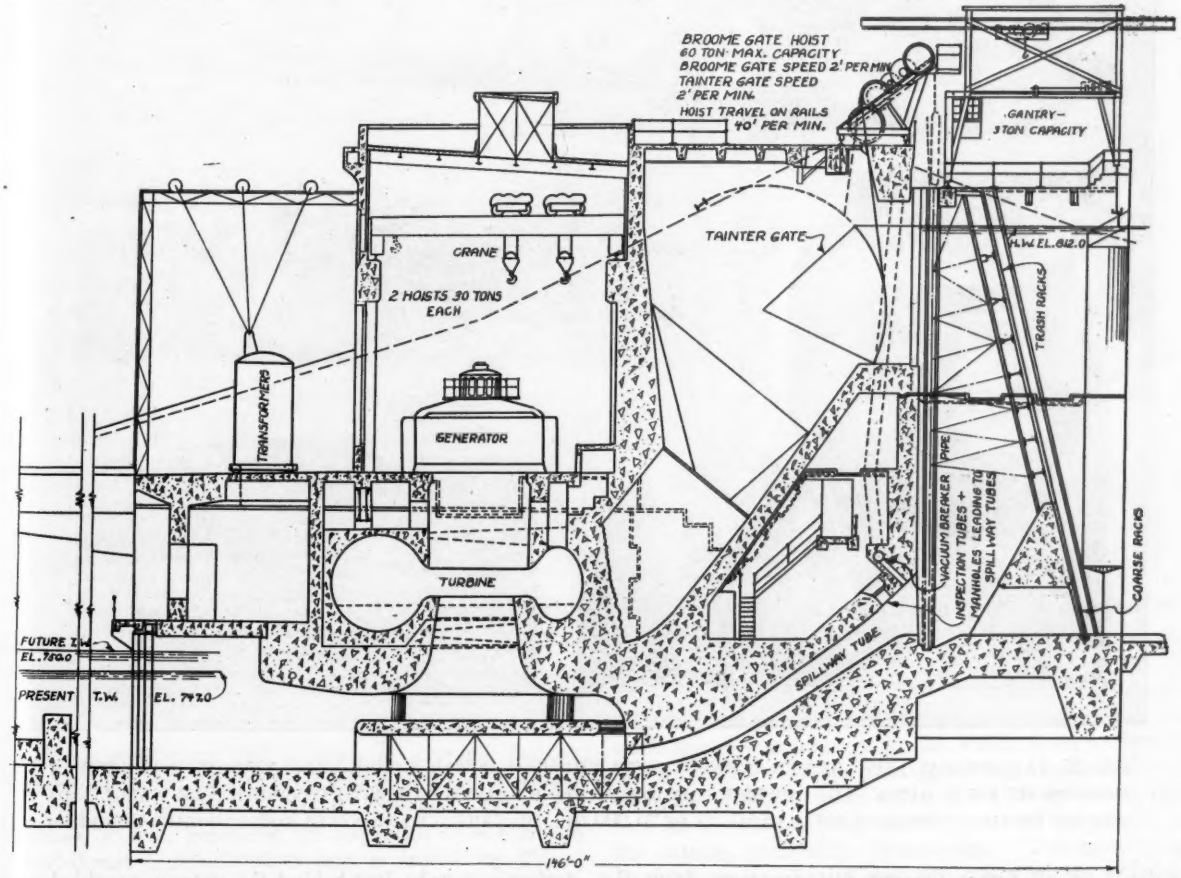


FIG. 1. SECTION THROUGH POWER HOUSE, SHOWING HYDRAUCONE TABLE TYPE DRAFT TUBE AND CONDUIT SPILLWAY

Hodenpyl Dam project consists of a concrete power house structure as shown in Figs. 1 and 2E, flanked on either side by water-deposited sand embankments having thin concrete core walls, built over steel sheet piling cutoffs driven into the underlying earth. The standing head is 68 ft.; operating head, 65 ft. Hard clay foundation was available for the power house and higher sections of the embankment, the balance being built on sand and gravel, dependence being placed on sheet piling and corewall for water tightness. This dam, like the others of this system, is built in a region of heavy glacial debris some 800 ft. thick. The river flows swiftly through a narrow winding valley which it has cut to a depth of 100 to 200 ft. below the surrounding sand plains. The river bed is usually in or close to clay strata of widely varying thickness, pitch and extent. All power houses of the system are of heavily reinforced

*Civil and Hydraulic Engineer, Commonwealth Power Corp., Construction Superintendent on Hodenpyl Dam project.

concrete, placed on clay whenever available, otherwise supported on round wood piling, and provided with deep steel sheet piling cutoffs.

The power house, a cross-section of which is shown in Fig. 1, represents a type of structure developed for the foundation conditions in this region, with a few improvements indicated by past experience. It is 107 ft. 8 in. from base slab toothings to roof, 105 ft. wide and 146 ft. long up and downstream, containing 32,000 yd. of concrete and 1000 t. of reinforcing, weighing about 65,000 t. and resisting a water pressure of 41,000 t. It is designed to act as a monolithic block, with the resultant of all forces passing just upstream from the center, thus insuring uniform base pressure, with no overturning tendency whatever. The heavy clay base slab toothings resist the sliding component. No difficulty has ever been experienced with this type of structure.

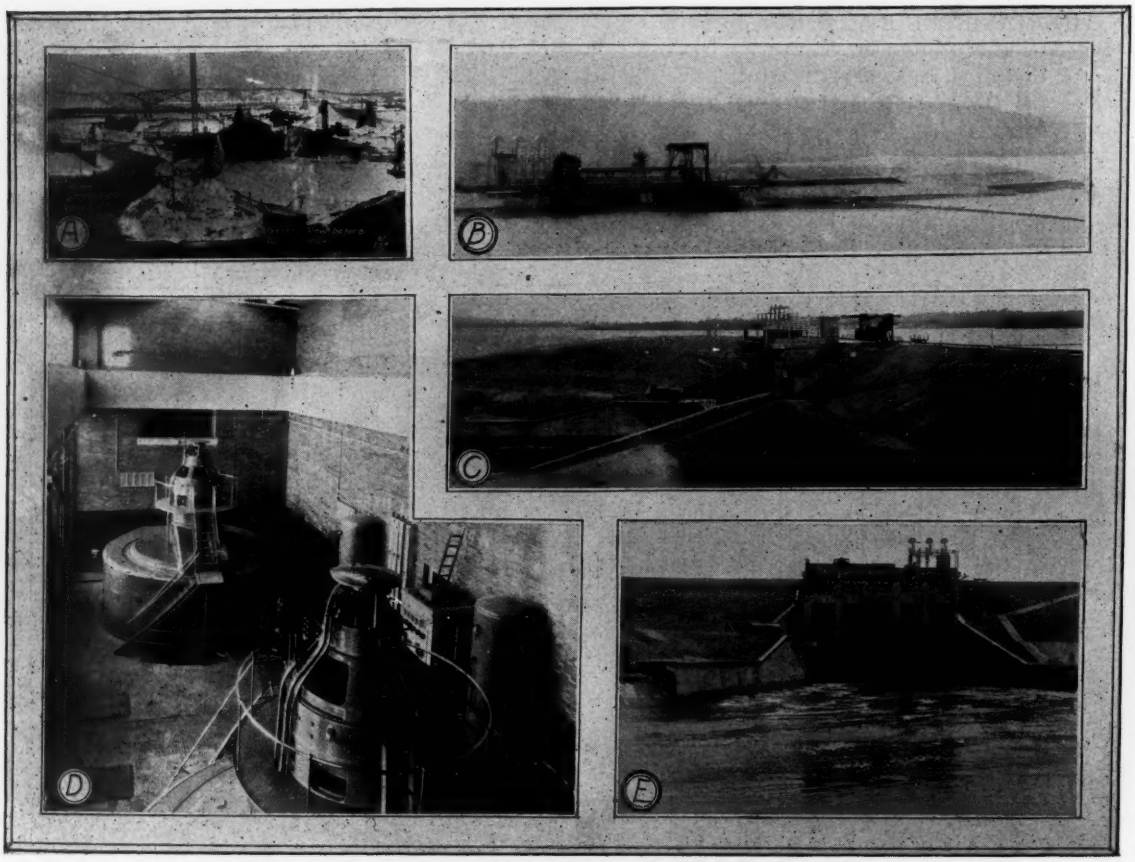


FIG. 2. (A) GENERAL VIEW BEFORE TURNING RIVER THROUGH POWER HOUSE. (B) LOOKING DOWNSTREAM TOWARDS SPILLWAY GATES. (C) POWER HOUSE IS FLANKED BY EARTH DAM WITH CONCRETE CORE WALLS. (D) TWO GENERATING UNITS GIVE TOTAL CAPACITY OF 25,000 HP. (E) TAILRACE AND POWER HOUSE LOOKING UPSTREAM

Conduit Spillways are Installed in Concrete Power House Block

Spilling capacity is provided by a conduit spillway, Fig. 1, beneath the power house, a design developed and patented by William W. Tefft, chief engineer, and already proved successful and economical at the Alcona and Mio developments on the Au Sable River. Excess water is passed through a set of six tubes having welded steel plate lining, from forebay to draft tubes, thus utilizing space otherwise wasted in the mass of concrete forming the power house base and also inducing additional draft head on the turbines. This construction eliminates the cost of outdoor spillways, which offer considerable operating difficulties in this latitude. These tubes are controlled by 10-ft. by 13-ft., caterpillar-type, rectangular steel gates set behind the trash racks as shown and operated by a motor-driven hoist traveling on a track across the penstock deck. Any one gate can be operated by the station operator from the generator room without assistance. An inspection manhole, entering each tube just behind the gate, is provided with heavy glass bull's eyes in the cover to allow visual evidence of spilling condition. Shape of tube, kind and anchorage of lining, form of entrance and type of gates have been developed to a point where hydraulic difficulties have been eliminated. These six tubes alone provide capacity considerably over twice that of any flood on record in this century. With wheel capacity and an emergency spillway constructed at the far end of the embankment 4000 ft. from the power house, a total spilling capacity of eight times the maximum flood is provided.

Two duplicate, vertical-type, single-runner Allis-Chalmers Mfg. Co. generating units, Fig. 2D, are sup-

plied with water through the largest steel plate scroll cases manufactured to date. Entrance is controlled by a pair of 20-ft. by 20-ft. steel tainter gates to each penstock. These gates are operated by the same hoist that operates the spillway gates. Scroll cases are backed up by mass concrete for support and preservation, also to damp out vibrations, aid rigidity, and the like. These cases were electrically welded throughout and are remarkably tight. Hydraucone table-type draft tubes are well adapted to this type spillway. The spilled water, passing in an unbroken jet beneath the table, exerts a drag all around the edges, appreciably increasing the draft head.

ience between the units. All 7500-v. apparatus is placed in a concrete bus and switch structure located in the basement downstream from the scroll cases. These busses connect to 140,000-v. transformers placed on the deck above, just downstream from generator room. The 140,000-v. switch is on the same deck adjacent to the transformers, surmounted by a steel structure supporting the 140,000-v. bus and outgoing lines. Oxide film lighting arresters are placed on the generator room roof, as shown in Fig. 2E.

Earth embankments, which flank the power house structure on either side, have a total length of 4200 ft., impounding a pond of 1850 acres. Through the old

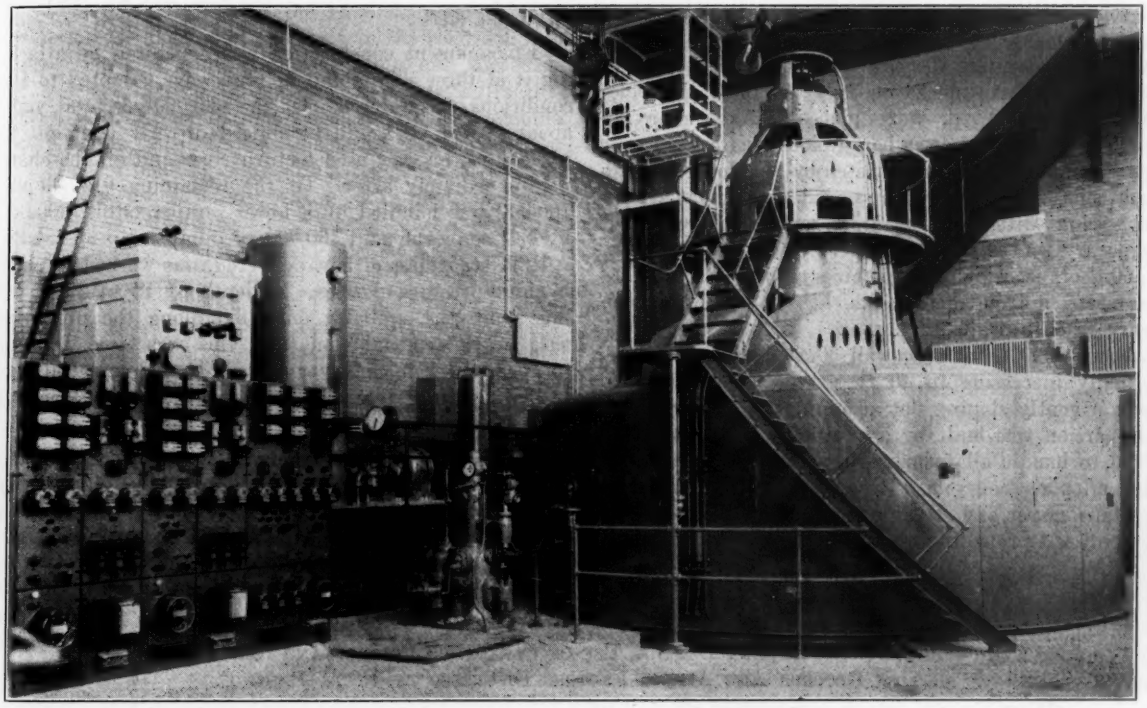


FIG. 3. EACH 12,500-HP. GENERATING UNIT HAS TWO EXCITERS TO INSURE STABILITY WHEN WEAK GENERATOR FIELD IS NEEDED

GENERATING UNITS HAVE UNUSUAL ARRANGEMENT OF EXCITERS

Each generating unit consists of a single runner, developing about 12,500 hp., according to preliminary test, direct connected to a 7500-v., 8888-kv.a., 120-r.p.m., 3-phase, 30-cycle generator, all suspended from a Kingsbury thrust bearing. Each unit is excited by 250-v., shunt-wound exciter, which in turn is excited by a 125-v., self-excited unit, both mounted on the main shaft above the thrust bearing. This unusual arrangement of exciters, shown in Figs. 1 and 3, is to insure stability of operation under conditions necessitating a weak generator field. Field regulation is accomplished by electrically-operated and interlocked rheostats in the fields of the auxiliary exciter, the main exciter and the generator, so arranged that they are operated by one double-throw control switch and keep the fields of the exciters well above the knee of the saturation curve at all times.

Switchboard, governors and other controls are at generator floor level, Fig. 3, and placed for convenience between the units. All 7500-v. apparatus is placed in a concrete bus and switch structure located in the basement downstream from the scroll cases. These busses connect to 140,000-v. transformers placed on the deck above, just downstream from generator room. The 140,000-v. switch is on the same deck adjacent to the transformers, surmounted by a steel structure supporting the 140,000-v. bus and outgoing lines. Oxide film lighting arresters are placed on the generator room roof, as shown in Fig. 2E.

Earth embankments, which flank the power house structure on either side, have a total length of 4200 ft., impounding a pond of 1850 acres. Through the old river bed this embankment is 82 ft. high and 600 ft. wide at the base. These embankments are built of fine sand, the only available material, which is too uniformly fine to permit of water grading by any economical construction means so as to secure a relatively impervious core at the center with coarser material deposited on the outside, preferably downstream. The underlying glacial deposit is partly clay hardpan, variable in thickness and extent, and more largely water bearing gravel and coarse sand, requiring an impervious cutoff. For these reasons the standard type of concrete core wall embankment was used throughout. Under the existing conditions it apparently costs no more than a puddled core embankment, and has the added advantage of certainty and safety. These embankments required 660,000 yd. of sand fill, 6000 yd. of concrete core wall, and 556 t. of steel sheet piling.

Some rather unusual and interesting construction methods were devised to hasten the completion of this work, which started in May, 1924, and was pushed so

that the river was closed on December 15, 1924, and the plant went into continuous power production July 5, 1925. To meet this schedule, it was necessary to invest heavily in construction equipment and to attack the embankment work at several points. Figure 2A shows the project just before the river was turned through the power house spillways.

The concrete plant consisted of two 33-ft. Austin cube mixers supplying two 220-ft. elevator steel towers placed on a hill across the river from the power house. Chutes were suspended by a high line carried over these towers and to a 180-ft. tail tower at the power-house, from which point distribution was made by a 100-ft. swinging boom from the tail tower. All gravel, sand and cement was handled by belt conveyors. This plant was supplemented by a single 33-ft. mixer and a 60-ft. wood tower adjoining the power house. The first power house concrete was placed on July 25, 1924. In October, 1924, 10,200 yd. were placed. As winter approached the entire power house block was housed over with a frame structure and heated by air blown through steam coils, so that work proceeded throughout winter and spring without any interference from weather. Temporary timber craneways were constructed to carry the 60-t. crane, which set machinery within this enclosure, taking it from the cars which were run in on temporary track beneath the crane.

About 2000 ft. of core wall 30 ft. high at one end, gradually increasing to 40 ft. at the other, extended across a gently sloping flat adjoining the power house. This portion was built by a cantilever traveller which served to handle all form work, as well as to mix, elevate and place concrete. It consisted of a steel frame with bins, mixer and elevator mounted on the base platform, all self-propelling on an 18-ft. gage track. Material was supplied by a locomotive crane claiming from cars on a standard gage track alongside. Four sets of wood forms faced with galvanized sheet iron, 30 ft. long and the full height of the wall, were so spread that no sets ever passed.

Increasing height was obtained by additional bottom sections. The wall was 12 in. thick for the top 20 ft., 18 in. thick below this. A set was usually filled in 2½ hr. and stripped the following day. Forms broke only once and no wall was ever lost or damaged. A schedule of ten 30-ft. sections a week was maintained throughout. Total labor cost including track building, placing footings separately, erecting and dismantling traveller, building forms, providing materials, and the like, was $6.40 per yd.

Embankment construction was expedited by attacking it at three points and in four ways, adapted to the conditions encountered. Of the 660,000-yd. total, only about 50,000 yd. could be sluiced directly from pit to place, and this was used to turn river and fill the channel immediately after. Of the remaining 610,000 yd. 160,000 was handled by a tower scraper outfit, 300,000 by belt conveyor, and 150,000 by dump train on trestle. All fill, regardless of how delivered, was washed to place by high-pressure nozzles. A depth of 12 to 25 ft. of fine sand was available on a flat along the upstream side of the embankment, and this was used for the scraper and belt conveyor. Train-hauled material was loaded by drag line and shovel at borrow pits about 1000 ft. from dump.

William W. Tefft is chief engineer in charge of design; E. M. Burd, civil and hydraulic engineer, was construction superintendent; H. N. Tuley was resident engineer.

Operating Ice Plants at Lowest Cost

ATTENTION TO PLANT DETAILS, USE OF CLEARANCE POCKETS AND KEEPING OF RECORDS ARE AMONG FACTORS DISCUSSED BY N. A. P. R. E.

AT A RECENT meeting of New York Chapter No. 2, N. A. P. R. E., J. R. Bernd, chief engineer of the Fulton Ice Co. and honorary president of the chapter, delivered a most interesting paper on Making Ice at Lowest Cost. Mr. Bernd spoke as follows:

How can an operating engineer determine that he is making ice at the least possible power cost in his plant? When an operating engineer takes over a plant, he is looked up to by every member of the crew to lay down the conditions under which the plant is to be operated. As all plants differ somewhat as to the best method to be employed, let us assume the main features of a plant and say the plant has fourteen 300-lb. cans to the ton at a brine temperature of 14 deg., has a condenser pressure of 175 lb. with 300 ft. of 1¼-in. pipe per ton in the freezing tanks. Ammonia compressors connected to constant speed motors. Piston displacement 7 cu. ft. per min. per ton ice. The compressors are connected direct to suction header at the tanks. Assuming the plant to be properly charged with ammonia and brine, the condenser supplied with the proper amount of water, if the circulation density and proper level of brine is maintained, if the ice is harvested as soon as made and if the suction pipe temperature is kept near the brine temperature, the operator should make capacity with ease.

With a correct record of conditions kept from day to day, whenever the capacity falls off or the power consumption increases, the record ought to show up the trouble. But a correct record even will not always keep the old ship on an even keel. I will cite one instance.

FREEZING COILS TO BE LEVEL

A plant with four tanks was designed to make 180 tons of ice, maximum capacity. The plant made the capacity with apparent ease. But the powers that be claimed that the suction temperature was too low causing greater power cost per ton than was necessary. It was agreed among the three watch engineers that the No. 4 tank was the jinx. The records showed that the No. 4 tank was always behind and needed more attention than the others. Finally it was agreed that it must be the brine circulation. The following winter the tank was stripped and the bulkhead examined; it was found in first class shape. It was also discovered that the tank was low at one corner a little more than 1½ in. The powers that be claimed that the low corner had nothing to do with the tank and that if the tank got its proper share of ammonia required to make the ice, it would make the ice—and that was that. But since we had gone that far and as it was the only thing that was not like

the other tanks, we left the tank as it was but levelled the coils. It was an easy thing to do as the brine gave the level, so we raised the coils, tank top, and all by putting shims under the coil stands. The next year the plant was pushed to 200 tons during July and August with a suction pipe temperature higher than the brine temperature and with a lower power cost per ton. So you will see that a correct record will not always show up the defect. But it will point the way.

Now, if the compressors of this plant, driven by constant speed motors have no clearance pockets, the engineer cannot attain the lower power consumption possible. Because then the engineer can only increase his ice production by opening the expansion valve more. Increasing the amount of ammonia in the coils will also increase the heat transfer between coils and the brine and will not materially decrease the temperature difference. But the compressor will not allow the ammonia to stay in the coils. The suction temperature will drop to the corresponding saturation temperature of the liquid. The excess liquid will pass through the compressor, wash out the oil, and power consumption per ton of ice will increase.

Trapping of Unevaporated Liquid

Various efforts have been made to overcome this increase in power cost at increased production. Accumulators are installed in the suction pipe between machine and tanks to separate the entrained liquid and return it to the tank but they fail to do so on account of coil friction, the pressure being greater at the liquid inlet than at the gas outlet of the coils. The most successful device so far is a trap placed in the suction line between the tank and compressors of sufficient dimensions to accommodate a coil containing enough pipe surface to cool the warm liquid on its way to the tank, thus relieving the tank of this work, evaporating the spill-over liquid, raising the suction gas to somewhere near the brine temperature and bringing the compressor power consumption back to normal, with increased ice production.

Advantage of Clearance Pockets

Now, since the temperature difference controls the amount of ice the plant makes and determines the temperature of the suction, a suction temperature near the brine temperature is best. Operating with yet lower gas temperature would give more capacity, but unfortunately, the line falls off so abruptly that to attempt to keep the suction gas below the brine temperature is not impossible but rather impractical. For there is a certain point at which the suction temperature is as low as the boiling point of the liquid ammonia where liquid is likely to reach the compressor cylinder. When operating a constant speed compressor without clearance pockets, the only thing that can be done is to choke the expansion valve. This increases the temperature difference in the coils, especially if the warm liquid is fed direct from the receiver to the freezing tank. The ammonia in the coils will then boil at a greater rate, causing more liquid to pass through the machine, thus increasing the demand for power. But, if the compressor is equipped with clearance pockets, opening say the 12 per cent pocket will reduce the temperature difference. Then you can choke the expansion valve, in fifteen minutes close the clearance pocket and operate at normal consumption without increase of demand. But if you have no clearance pockets, the demand will increase and it will be at least an hour before you can again operate at normal power consumption and ice production.

It would take too long to go into every detail of plant design, construction and operation, ice production and power cost. But I will try to point out some of the main points that have a bearing on power consumption.

Venturi Flow Meters Indispensable

In the first place, if a plant is not equipped with a Venturi liquid ammonia meter, it is utterly impossible even to approach economy in power consumption. As the suction pressure, and its temperature, is the true indicator of the temperature difference and therefore of the rate at which a freezing tank produces ice, this suction pressure should be kept as nearly constant as possible. One pound change in suction pressure, as from 18 lb. to 19 lb. at the Fulton Ice Co. plant, New York, means 25 and a fraction tons difference in ice produced for 24 hr. You cannot keep a constant suction pressure without a Venturi meter on water and ammonia, as any fluctuation of water rate will affect the feed of ammonia. In this plant one pound change in condenser pressure will increase or decrease the ammonia feed 3 lb. per min. at 14-deg. brine. That means five and a fraction tons of ice increase or decrease per 24 hr.

Mercury U Tube for Suction Pressure

Most plants are equipped with suction gages that are calibrated 5 lb. to one-quarter of an inch. With such gages it is difficult to detect a variation of one or two pounds. At the Fulton plant, we use a mercury column, calibrated a little more than two inches to the pound. Half-pound variations can easily be discerned, even at 50-ft. distance. The saturation temperature of the suction gas is also laid off on this gage so the operator can see at a glance what it is; otherwise, he would have to refer to an ammonia table. I have never yet met an operating engineer who could tell you offhand the saturation temperature corresponding to the pressure without a table, myself included.

Operating in a plant equipped with these accessories, you can forget about suction temperature and probably look at it only when writing up the log. This is not intended as advertisement for the engineers who designed the Fulton plant, but I believe the achievement merits mention anywhere, any time.

Some ice machine manufacturers realizing this, have installed these accessories and have made every endeavor to make their compressors flexible, but several of our most prominent manufacturers still build them without clearance pockets. Of course they have their reasons and to my mind they must be big ones. You can't tell me that they don't know better, because that would be an insult to their intelligence. On the other hand, I believe that they think the average operating engineer and plant owner don't know any better and for that reason think they can get by with it. So after all, the blame must be placed on the operating engineer if he stands by and the compressor is put in without clear-

ance pockets and he has to depend on the expansion valve for compressor performance.

Importance of Correct Log

Get in the habit of keeping a correct record of your plant and you will soon begin to notice smaller things than a moving train or ship. You will index your B.t.u.'s and have them where you will be able to put your hands on them when you want to use them to compare results instead of looking for them in a fog in the backyard. You will then be able to calculate why you can't operate a constant speed compressor without clearance pockets at an economical suction pressure and temperature, and at lowest possible power cost per ton of ice.

Fine Points in Operating

I used to kid myself and believe that if 14-deg. brine made a certain amount of ice and we operated with from 13 to 15-deg. brine, it would give us an average of 14-deg. brine and we would get 14-deg. brine results. That may be true in a great many things but it won't do in an ice plant. When your brine goes above 14 deg., you lose ice and if you want to make it up, you have to pay double in power cost. When operating at 13 deg. you are expending more power than at 14 deg.

We have at the Fulton plant, 4 freezing tanks, 2160 300-lb. cans and about 50,000 ft. of 1¼-in. pipe. One degree change, as from 13 to 14 deg. means 25 and a fraction tons less ice in 24 hr., provided the ice is pulled as it is made.

My crew claimed no plant could be operated and maintained at a constant brine temperature. But by comparing methods and results, they soon discovered that if the Venturi put the ammonia into the tank coils, the main thing to watch was the ice puller and forget all about the suction pressure as they found the puller is what changes the suction pressure, by pulling out of turn.

If you have no Venturi meter measuring the flow of liquid ammonia, and have to rely on receiver gage to indicate the amount of liquid in freezing tank coils, and the level fluctuates, either the drains from condenser to receiver are trapped, or some freezing tank coils are out of level more than one diameter of a pipe, or the quantity of water circulating over the condenser fluctuates, and you are out of luck. The exact relations between pressures and output above indicated were found to exist at the Fulton ice plant because we compared results from records kept as nearly correct as we can.

Abandon Wet Compression

I have heard operating men say with pride that they very seldom touch the expansion valve on their watch. Well, all I have to say to that is that as a rule the suction pipe has an ample hole in it to take care of the liquid the tank can't use.

I have also heard a compressor trying to tell an operator that the expansion valve was open too much but he just didn't understand compressor language. If the compressor had been equipped with clearance pockets and he had opened one of them, he would have been surprised to find that his power consumption would have dropped, that his suction pressure would have gone up a pound or so and the brine temperature remained the same and he would not need to touch his expansion valve. But his temperature difference would have been less.

If a plant can produce 200 t. of ice in 24 hr. with 8-deg. difference, it will produce 100 t. at 4-deg. difference, 50 t. at 2-deg. difference and 25 t. at 1-deg. difference, provided all cans are used for 25 and 200-t. production and the can water remains at the same temperature.

As for the suction pressure, well, you will just simply have to look at the gage and see what it is, for I cannot tell you except from the record.

The power cost per ton will be the same provided you can split the auxiliaries in proportion to the tonnage, but you will have to take into consideration the transformer loss, as that item will be proportionately more at 25 t. than at 200 t.

Team Work of Crew

I have read a good many articles on the relations that should exist between the chief engineer and his crew. I have tried out some of the ideas but always had friction. I have come to the conclusion, therefore, that the relation which should exist between the chief and the members of his crew should be the same as between a father and his sons and that every member of the crew should share in the responsibility of operating the plant.

We have issued orders in our plant that no one is allowed to make repairs without first reporting the defect or damage to the engineer on watch. The engineer enters the defect in a book on the left-hand page, puts down the time and by whom reported. It's up to the engineer to decide whether repairs are to be made immediately or if they can be deferred to a more favorable time. This is noted in the book also. Then when repairs are made, it is entered on the right-hand page, date, time and by whom. This always leaves a blank space until the repairs are made and acts as a reminder. In this way, every man in the crew is given a hand in operating the plant and verifies the old adage that a "stitch in time saves nine." And you will be surprised how quickly it eliminates the "don't cares" as well as break-downs or interruption of operation.

In discussing Mr. Bernd's paper, Charles H. Herter was pleased that Mr. Bernd came out so frankly in favor of clearance devices. He just had bought two clearance heads and believed that as a result of this meeting most engineers would want such heads, especially as they can be readily attached to most new and old machines. He said it should be remembered that cylinder heads with clearance pockets act precisely the same as ordinary cylinder heads do, in that the full capacity is retained until it is decided to enlarge temporarily the clearance volume, for the purpose of unloading that end of the cylinder, thereby keeping the power consumption below a predetermined limit.

Often during cool weather the load on the plant is 50 to 100 kw. below the peak set for that week, leaving a surplus of power which has to be paid for anyway. If then a machine with clearance pockets is available, such machine can be switched into service to help the ice production with scarcely any increase in cost of power. In this manner the engineer can often improve the load factor from 90 to 97 per cent.

School Book Plant Has Double Power Service

GINN AND CO. HAS SMALL PLANT FOR GENERATING POWER AND HEAT IN WINTER WITH PROVISION FOR PURCHASING OUTSIDE POWER IN SUMMER. BY G. H. KIMBALL

IN CAMBRIDGE, MASS., The Athenaeum Press, of which Ginn and Co. is the proprietor, is one of the largest concerns in the world engaged solely in the manufacture of school books. Adjoining the main buildings is the power plant with a floor space of 43 ft. by 104 ft.

Built in 1896, the original plant was equipped with two small engines and two return tubular boilers 16 by 72 in. in diameter. After a time another boiler was added and also larger engines, so that by 1920 the engine units consisted of one 250-kw. d. c. generator driven by a 20 by 40-in. four-valve Brown engine, running at 100 r.p.m., a 125-kw. generator driven by a 17 by 16-in. necessary to remove large quantities of material on account of the deep ashpits made necessary by the use of the hand stokers.

WATER-TUBE BOILERS REPLACE FIRE-TUBE TYPES

As shown in Fig. 1, two 300-hp. Babcock and Wilcox water-tube boilers, built for 200-lb. service, replaced the old fire-tube boilers. For a small installation there were many problems in arranging the layout of the smoke breeching and piping. The boilers were equipped with Bailey meters, Vulcan mechanical soot blowers, Gibby hand stokers, Carling under grate blowers and Edward

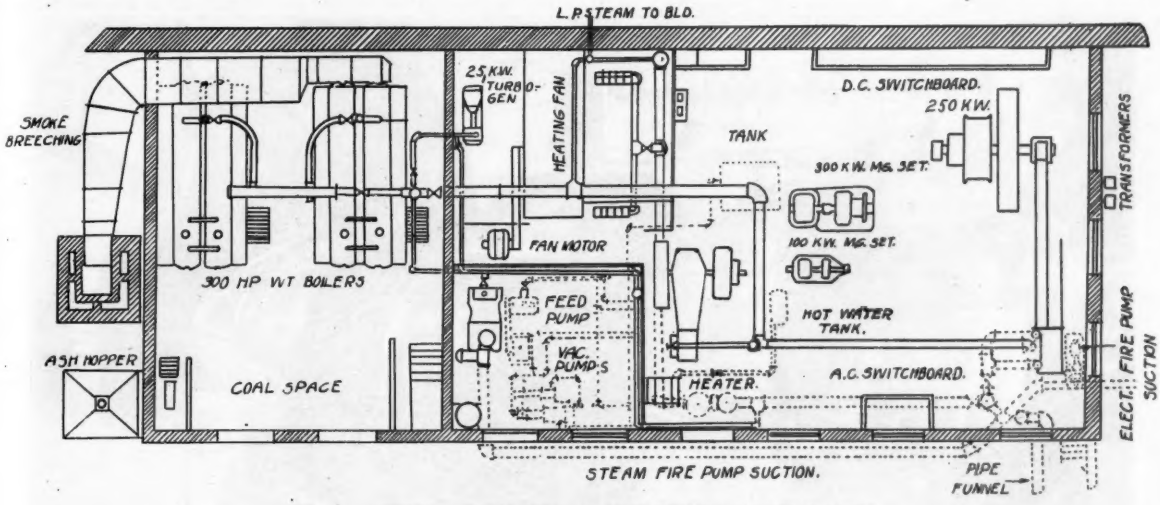


FIG. 1. THIS IS A PLAN VIEW OF THE WHOLE POWER PLANT

American Ball engine, running at 250 r.p.m., a 100-kw. generator driven by a Brown 15 by 36-in. engine running at 100 r.p.m., and a 22½-kw. generator belted to a Sturtevant 10½ by 14-in. engine.

Since two of the boilers were 25 yr. old and on account of the pressure being limited to 100 lb. per sq. in., plans were made late in 1921 to install boilers of larger capacity that would be built to carry a higher working pressure. This job had some difficulties on account of the fact that there was no opportunity to shut down the plant during the installation and also on account of the lack of space, since the three return tubular boilers occupied all of the boiler room except a 4-ft. aisle on the south side. The plan followed was to remove one of the return tubular boilers and to run the plant with the other two, then prepare the foundations and install a water-tube boiler in the space provided, make all the necessary steam connections as well as those to the chimney and use this first new boiler to carry the load while a second one of the same size was being installed in place of the two older boilers.

Before anything could be done towards the new installation, it was necessary to rebuild nearly all of the roof of the boiler house and raise the main steam header to make temporary connections to the old boilers to be used until the first new boiler was ready for service. In preparing the foundations which were on piles, it was non-return valves. As it was decided to operate with a pressure of 125 lb. at the start on account of the engine not being built to handle a higher pressure, an extra nozzle was provided on the main steam header for a connection to a new engine unit which was then contemplated. Provision also was made in the main steam pipe to install a reducing valve which would reduce the steam from 180 lb. to 125 lb. pressure for the older engines after a new engine was installed.

DECIDE TO PURCHASE POWER

At the beginning of 1923 when investigations were being made regarding the installation of a new generating unit, it was decided that one of 500-kw. capacity would be needed. At this time also, the question of using central station power was considered and there were certain points in its favor. First, the method of obtaining fuel; originally all of the fuel came by barge to a lot nearby and was unloaded by a neighboring coal company. At this time the coal company closed up its yard, which prevented the discharge of barges as before. Second, there was no large storage space for fuel adjacent to the power plant which might cause difficulty in the winter months or at other times when fuel might be scarce. Third, the expense incident to the installation of a generating unit was excessive for a plant of this capacity. It was decided, therefore, to purchase outside power.

After considerable study, it was decided that it would be unwise to change over all of the motors of which there were about 350 using direct current, ranging in size from ¼ to 30 hp., and it was also felt that during the months when steam was needed for heating, it would be advantageous to operate the engines and use the exhaust steam so it was decided to install motor generator sets for the power current and feed the central station current directly to the lighting circuits through transformers.

After removing the 100-kw. engine unit a 300-kw. and a 100-kw. motor generator set were located on the same foundation, the motors being driven by 2300-v., 3-phase, alternating current. Two new switchboards were installed, one for alternating current only and one for handling direct current and alternating current for lighting circuits. Since the plant had always been heating, and whatever power is generated will be considered purely as a by-product and this will make a minimum amount of coal necessary, since all other requirements for power are made on a central station. The cost of such an installation in itself is considerable, but it is expected that substantial economies will be effected over those in force with the previous arrangement, and it is quite probable that had a new generating unit been installed, it would have necessitated some additional expenditure in the boiler room on account of the necessity of providing more draft since the chimney is only 100 ft. high and of comparatively small cross-sectional area. Also the cost of up-keep for the boiler plant would have been somewhat increased. The system has not been in operation long enough, however, to determine the exact cost of operation under the new arrangement.

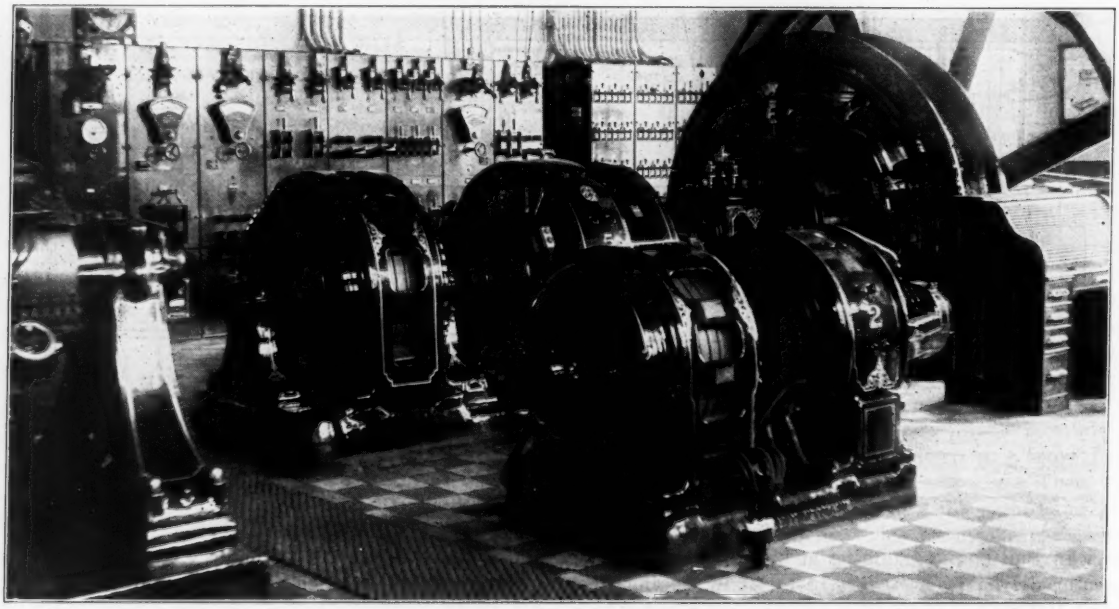


FIG. 2. THIS IS THE ENGINE ROOM WITH THE D. C. SWITCHBOARD, MOTOR-GENERATOR SETS, AND AN ENGINE-DRIVEN 250-KW. GENERATOR

equipped with a steam fire pump, for which it was necessary to keep steam at all times, in order to provide the necessary protection when the fires were out, a motor-driven pump of 750 gal. capacity per minute, driven by a 75-hp., 2300-v., 3-phase motor was installed.

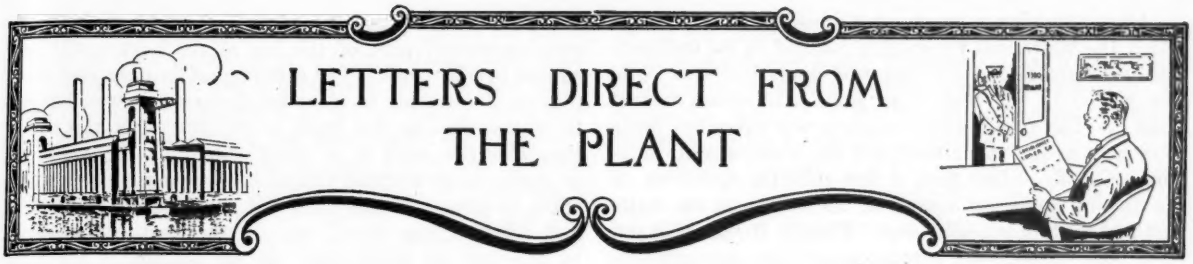
Purchased Power to Be Used in Summer

It is expected that the plant will be operated as follows: from May 1 until October 1, central station current will be used exclusively and as steam is needed for heating during the hours that the plant is in operation, an engine driven unit will be thrown in parallel with the motor generator sets and the load adjusted to supply the necessary amount of steam to the heating system, and this arrangement will prevail throughout the winter months until May 1, no steam being allowed to escape into the atmosphere and the amount of generated power depending entirely upon the temperature.

Arrangements regarding boiler room force to operate the plant during these two seasons are put in effect on May 1 and October 1 of each year. With this arrangement, it will be seen that no steam is made except for

Throughout the building the heating system is about one-half indirect and the remainder direct radiation, the vacuum system being employed. In the power house there is installed a large Sturtevant fan driven by a 30-hp. motor which supplies the air for indirect heating.

In the pump room are two vacuum pumps, a direct acting steam pump, and a triplex, motor-driven, boiler feed pump. All of the return condensate from the heating system is discharged into a National cast-iron receiving tank of 800 gal. capacity and from there is pumped through a closed feed water heater to the boilers. On the main feed line is a Bailey fluid meter which records the flow in thousands of pounds per hr., the temperature of the feed water and the steam pressure in the boilers. This meter also is equipped with an intergrating arrangement, which shows the total flow over any period of time. The water supplied to the power house from the city mains is metered, and the heating system is equipped with a Bristol recording pressure and vacuum gage while the draft is regulated by a Mason automatic damper regulator.



Water Hammer Caused by Undrained Pockets

SEVERAL years ago, after taking charge of a boiler room, I was surprised to find several dangerous piping installations. Figure 1 shows two horizontal return tubular boilers with dangerous water pocket main connections. Before I came, there was no tap and drain as shown. Extreme care had been used in cutting in these boilers. I wasted no time in setting a trap and draining these pockets as shown.

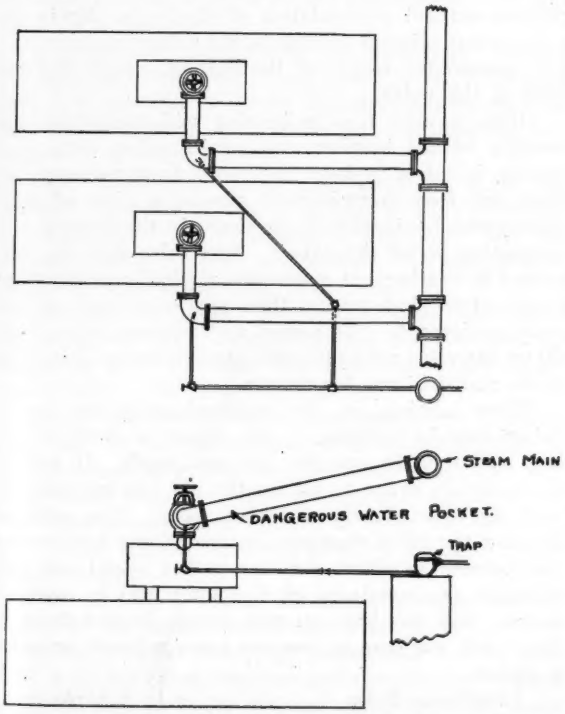


FIG. 1. THIS METHOD OF CONNECTING THE HEADER TO THE BOILERS CAUSED A DANGEROUS WATER POCKET

One morning, on coming to work I found the 4-in. valve controlling live steam to the shop, badly shattered. Investigation disclosed that the night watchman had opened it too suddenly, allowing high pressure steam to strike some water pocketed above the shop valve. When this valve was shut the boiler pressure behind this reducing valve forced through enough steam to build up boiler pressure between the reducing valve and the shop service line. When the shop valve was opened by the watchman, enough high pressure steam was allowed to come in contact with this trapped water to cause serious water hammer, which in turn broke the valve.

As shown in Fig. 2 this was remedied by providing a drain and trap for the water caught between the reducing valve and the shop valve. Also, I installed a drain line from the main line above the shop valve, to a radiator. This adequately drained the water that collected in the riser above the shop valve and at the same time eliminated the necessity of another trap.

Moline, Ill. ROBERT A. ALTHAUS.

Does It Pay to Remove Oil from Waste?

SINCE THERE is a large number of waste washers and oil separators in use in various power plants and industrial concerns the question often arises as to the economy of such methods. In most cases they are found to be paying investments but actual figures are lacking in many instances and even where available they are only

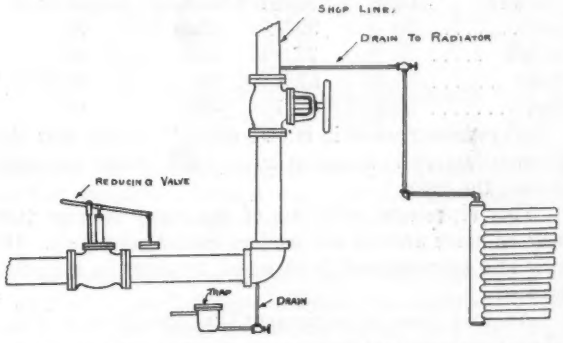


FIG. 2. WATER POCKETS ON THIS LINE WERE DRAINED BOTH ABOVE AND BELOW THE SUPPLY VALVE

partially complete so that it is difficult to determine the extent of saving.

In the first place some means must be at hand for the washing of the waste and for the removal of the oil. The most ingenious machine I ever saw for the removal of the oil, which is the first operation necessary in the reclamation of the waste, was an outfit made up by the power plant engineer. It consisted essentially of a small steam turbine mounted horizontally with a perforated cylinder fastened to the shaft and around this a stationary cylinder or retainer provided with a valve at the bottom for drawing off the oil. The entire top was covered, both the inner and the outer cylinder.

Oil soaked waste, placed in the inner cylinder, was revolved at 2600 r.p.m. so that the centrifugal action of the revolving mass would separate the oil from the waste. The oil was thrown through the perforations in the walls of the inner cylinder into the stationary receptacle from which it was drawn off into a container placed under the valve.

After removing as much oil as possible by centrifugal action the waste was thoroughly washed in an ordinary washing machine. Following this operation, the waste was placed in the centrifuge again and steam turned upon it. This preliminary steaming was given the waste to liven it as it was claimed that the waste would otherwise be stiff. After this, a few minutes operation of the turbine threw out almost all the water and the waste was removed practically dry. Finally it was laid out on a table placed over several steam coils for complete drying. The waste looked and felt like new material.

Oil removed from the waste was run through a filter and much of it reclaimed. This oil should not be used on high-class machinery but there are many places about the factory where it may be used to advantage.

Waste recovered in this manner is returned to the stock room. In many cases it is found superior to the new product as it is entirely sterilized and the employes can use it for wiping the hands without danger of infection in case of a cut or bruise.

I ran some experiments some time ago in an effort to determine how much oil a given waste would absorb. I soaked the waste and then let it drip until no more would drip off, after which I carefully weighed it. This procedure was carried out with four different grades of waste from the cheapest to the fancy grade. The results were as follows:

	Weight in grams			Per cent of total
Grade	Dry	Soaked	Absorbed	weight as oil
Low	30	99.5	69.5	70
Second	25	77.5	52.5	68
Third	19.5	57.5	36	62.5
Best	23.2	67.5	44.3	66

From these figures it is not difficult to see that the average factory is throwing away considerable lubricant during the year.

This represents only one of the many savings that may be made around our modern industrial plants. Oil may also be reclaimed from metal turnings in a similar manner.

Another piece of equipment that should be included when purchasing or making up a separator and washer is the oil filter. The oil removed from the waste and turnings cannot be used in the condition it comes out since much foreign matter is held in suspension and this will ruin any bearing on which the oil may be used. The only practical way to remove this foreign material is by a filter.

Waterloo, Iowa. C. C. HERMANN.

Oxy-Acetylene Torch Useful for Relining Bearings

NOT ONLY is the oxy-acetylene torch useful for welding and cutting but it is an ideal source of heat for removing babbit-metal from old bearings. The easily controlled flame saves much time in melting out the old metal and burning off the grease for cleaning the bearing mold. The tip used need not be large and should be kept in motion by playing over the old metal until it is all melted out but care should be exercised not to burn the metal. Playing the torch flame over the mold will burn the oil or grease and any other foreign matter, and so dry up the bearing that a wire brush will clean it perfectly.

Preheating the bearing mold for a new lining is a most important part of the job as the babbit will not adhere to cold metal. The difficulty of heating and then placing the bearing in place for the pour, is well known to anyone having this work to do, but using the torch simplifies the work to a great extent as the mandrel or shaft can be warmed up and the bearing molds heated while in place. The melting pot should then be heated, and after adding metal, supply the heat for melting by playing the torch flame on the bottom of the pot. Any temperature desired of bearing mold and pot metal can be obtained and a perfect pour made.

In addition to the economy of time and the convenience of using the torch for this work, it eliminates the dangers of injuring a bearing by chiseling out the old metal.

Quite often a worn or scored bearing can be repaired with the torch. The lining must first be washed with lye water, all traces of oil being removed. Using a filler rod of babbit-metal, the scores are built up and then the bearing scraped in.

Building up worn brasses and babbit-metal bearings requires skillful manipulation of the torch. Spots are built up and allowed to solidify, the welder working each spot toward the center of the bearing, completing the work at this point.

Often a weld near a bearing will necessitate the pouring of the bearing over again unless some precaution is taken to keep the metal from melting out. This can often be avoided by placing a piece of pipe, approximately the size of the shaft, in the bearing and circulating water through it. The valve gear on feed pumps is wearing out constantly, probably giving more trouble from lost motion than any other part of the plant equipment. The easiest and quickest repair is to fill up the valve rod heads with steel or bronze, using the torch, and drill out for the pin.

Worn bearings in the crosshead stand can be repaired best by welding in cast iron to a depth of one inch and drilling out for the rock shaft. It will be necessary, in order to fill up the old bearing space to back up with asbestos or carbon paste. The partition between the valve chambers on one of our feed pumps had become so pitted that the gasket would not hold although the remainder of the pump was in excellent shape. This was built up with bronze dressed down by hand, and has been in use two years without replacing a gasket.

Vermillion, S. D. L. A. COWLES.

Superheaters for H. R. T. Boilers

IN THE May 1 issue, p. 549, Chas. L. Anderson, reviewing my article of March 15, p. 389, entitled "Super-Heaters Are Needed for Small Plants," infers that in describing a simple form of superheater for h.r.t. boilers, giving some of its limitations and peculiarities, I ascribed "results which may be expected from all superheaters," and on that account I did not give superheating a square deal. The title of Mr. Anderson's article "Superheaters Should Give Uniform Temperatures," would seem to indicate that this feature usually is necessary.

Perhaps the field where superheaters are most extensively used is in connection with locomotives. In this practice the loads have extreme fluctuation accord-

ing to the train resistance with heavy trains on heavy grades at high speeds, or on a level at moderate speeds.

In the former case, the boiler may be pushed to its utmost, and if equipped with a superheater the higher gas temperature around the superheater coils, together with a high velocity of these gases about the coils and a high velocity of steam through them, will develop a much higher temperature of superheated steam than can be maintained when the locomotive operates on level track and at lower speeds. Therefore, there cannot be "a uniform temperature" here, but a variable one, which is not a disadvantage—as we shall show.

For instance, under heavy loads high superheat on locomotives tends to improve the engine economy at late cutoff. When high mean effective pressure is necessary, if the permissible maximum superheat is sufficiently high, as compared with the lower superheat imposed by light load conditions, the engine economy may be nearly the same, or better at late than at early cutoff, developing a flat, perhaps a drooping economy curve. A superheater, therefore, gives great advantage to the locomotive boiler at such a time when temporary high power is necessary.

A locomotive engineer on the Broadway Limited, running on the division from Crestline to Pittsburgh, once told me that he could operate his locomotive at high speed up the steepest grades and reach the top with his safety valves blowing off.

This condition of heavy peak loads also is not uncommon in small plants, therefore a high maximum boiler capacity can be secured in this way. See last sentence in my article, as follows: "A superheater, therefore, helps in carrying peak loads."

This discussion does not mean that at light loads high superheat temperatures are not desirable, but the conditions are often such that sufficiently high superheat at light loads cannot be obtained.

Nearly uniform superheat temperature may be necessary—say for Corliss engines or for power stations or special industrial operations—but great advantages still are obtained even with varying superheat temperatures. The temperatures which I stated as being the maximum for Corliss engines were supplied by leading engine manufacturers.

There are also a number of other advantages that are secured by the superheater for h.r.t. boilers, described in my article, namely: simplicity, accessibility to rear tube-sheet, drainage of superheater and adaptability to usual horizontal tubular boiler settings. Thus there are many small plants where such a superheater as described would be a great help.

Cincinnati, Ohio. J. B. STANWOOD.

Corrosion of Steel Chimneys Affected by Design

IN REFERENCE to the article by Charles C. Phelps, May 15 issue, p. 613, I was quite interested in the problem of corrosion of steel chimneys and, although having had no actual experience in their design and construction, I believe it would be an easy matter to prevent the collection of soot on the top of either inside or outside plates if the edges were made with a bevel.

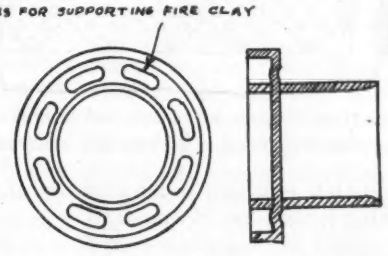
Such a design would, as far as I can see, shed water, cinders, soot or any other material. If the square edge of the lap is actually responsible for allowing conditions to form which will hasten corrosion, as Mr. Phelps states, it would seem that a beveled edge joint would be the regulation design. It will be interesting to hear from others as to their solution of this problem.

Toronto, Canada JAMES E. NOBLE.

Cast-Iron Sleeves Protect Fire-Tubes

IN REGARD to the article by Charles J. Virgin in the June 1 issue, p. 664, under the above title, I may state that I have had some experience with these sleeves. About 15 yr. ago, in some European countries, there was in use a device to protect leaky tubes by insertion of conical steel rings into the tube ends, but such a device proved impractical for sometimes, as a result of the expansion, it caused the tube plates to crack.

After several years, these steel rings passed out of use, giving place to a new method—that of the cast-iron sleeves. This latter method was first used on some transport ships, but later became popular in stationary plants. Cast-iron sleeves were in use, not only in England, but in other countries also.



THIS TYPE OF CAST-IRON SLEEVE FOR PROTECTING THE ENDS OF FIRE TUBES IS PROVIDED WITH AN ANNULAR SPACE FOR FIRE CLAY PACKING

As shown in the accompanying sketch, they are 2 in. long with a small flange. Before the insertion of the sleeve into the tube, the sleeve should be coated with fire clay. The empty space of the flange of the sleeve also should be filled with fire clay. Some users of cast-iron sleeves prefer to use asbestos instead of fire clay.

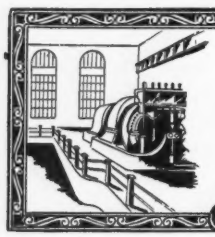
Generally the tubes leak at the rear end, at the point where the gases enter and the highest temperature is found. Cast-iron sleeves insulate the tube ends and part of the tube plate.

When tubes are already leaking the cast-iron sleeve can not prevent it. Before the insertion of sleeves into tube ends, the tubes must be expanded with a tube expander.

Objections to the use of such sleeves are: 1. They decrease the area of tube. 2. They prevent perfect tube cleaning. 3. They burn out with one or two months' service.

Chicago, Ill. ED. GEINERT.

YOU NEVER can tell how you're going to meet that fellow one, two, or five years from now. Don't, however, get scared at that and think that you must necessarily favor him, but give him a square and manly deal now and you will be in a position to do business with him when the next time comes; no matter how you both may be placed then.



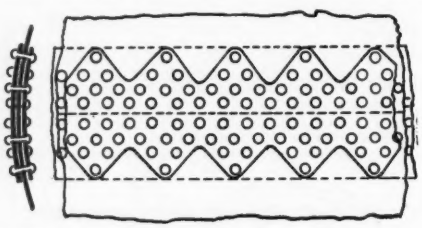
QUESTIONS AND ANSWERS

Quadruple Riveted Joint Has High Efficiency

How would you design a butt and double strap joint, quadruple-riveted, with all rivets in double shear, so that the efficiency of the joint will be 93 per cent?

V. H.

A. Since the ratio which the strength of a unit length of a riveted joint has to the same unit length



THIS QUADRUPLE-RIVETED BUTT AND DOUBLE STRAP JOINT OF THE SAW-TOOTH TYPE HAS THE HIGHEST EFFICIENCY

of the solid plate is known as the efficiency of the joint, the following items must be known:

A = strength of solid plate = $P \times t \times T S$.

B = strength of plate between rivet holes in the outer row = $(P - d)\ t \times T S$.

C = shearing strength of eight rivets in double shear, plus the shearing strength of three rivets in single shear = $N \times S \times a + n \times s \times a$.

D = strength of plate between rivet holes in the second row, plus the shearing strength of one rivet in single shear in the outer row = $(P - 2d)\ t \times T S + 1 \times s \times a$.

E = strength of plate between rivet holes in the third row, plus the shearing strength of two rivets in the second row in single shear and one rivet in single shear in the outer row = $(P - 4d)\ t \times T S + n \times s \times a$.

F = strength of plate between rivet holes in the second row, plus the crushing strength of butt strap in front of one rivet in the outer row = $(P - 2d)\ t \times T S + d \times b \times c$.

G = strength of plate between rivet holes in the third row, plus the crushing strength of butt strap in front of two rivets in the second row and one rivet in the outer row = $(P - 4d)\ t \times T S + n \times d \times b \times c$.

H = crushing strength of plate in front of eight rivets, plus the crushing strength of butt strap in front of three rivets = $N \times d \times t \times c + n \times s \times a$.

I = crushing strength of plate in front of eight rivets, plus the shearing strength of two rivets in the second row and one rivet in the outer row, in single shear = $N \times d \times t \times c + n \times s \times a$.

Divide B, C, D, E, F, G, H or I (whichever is the least) by A, and the quotient will be the efficiency of a butt and double strap joint, quadruple-riveted, as shown in the accompanying figure.

$t = \frac{1}{2}$ in. = 0.5 in. $\quad a = 0.6903$ sq. in.

$T S = 55{,}000$ lb. per sq. in. $\quad s = 44{,}000$ lb. per sq. in.

$b = \frac{7}{16}$ in. = 0.4375 in. $\quad S = 88{,}000$ lb. per sq. in.

$P = 15$ in. $\quad c = 95{,}000$ lb. per sq. in.

$d = \frac{15}{16}$ in. = 0.9375 in.

Number of rivets in single shear in a unit length of joint = 3.

Number of rivets in double shear in a unit length of joint = 8.

$A = 15 \times 0.5 \times 55{,}000 = 412{,}500$.

$B = (15 - 0.9375)\ 0.5 \times 55{,}000 = 386{,}718$.

$C = 8 \times 88{,}000 \times 0.6903 + 3 \times 44{,}000 \times 0.6903 = 577{,}090$.

$D = (15 - 2 \times 0.9375)\ 0.5 \times 55{,}000 + 1 \times 44{,}000 \times 0.6903 = 391{,}310$.

$E = (15 - 4 \times 0.9375)\ 0.5 \times 55{,}000 + 3 \times 44{,}000 \times 0.6903 = 400{,}494$.

$F = (15 - 2 \times 0.9375)\ 0.5 \times 55{,}000 + 0.9375 \times 0.4375 \times 95{,}000 = 399{,}902$.

$G = (15 - 4 \times 0.9375)\ 0.5 \times 55{,}000 + 3 \times 0.9375 \times 0.4375 \times 95{,}000 = 426{,}269$.

$H = 8 \times 0.9375 \times 0.5 \times 95{,}000 + 3 \times 0.9375 \times 0.4375 \times 95{,}000 = 473{,}145$.

$I = 8 \times 0.9375 \times 0.5 \times 95{,}000 + 3 \times 44{,}000 \times 0.6903 = 447{,}369$.

$$\frac{386{,}718\ (B)}{412{,}500\ (A)} = 0.937 = \text{efficiency of joint.}$$

These calculations may be found in the A. S. M. E. Boiler Construction Code and from the result it may be seen that this type of joint probably is the strongest that can be made, having an efficiency from 92 to 94 per cent, if designed as shown in the accompanying figure.

Cheap Coal Often Uneconomical

We have a small municipal light plant in our town equipped with typical 150-hp. h.r.t. boilers, set 3 ft. 6 in. above the grates. We are offered lump coal at $4.10 per ton, egg coal at $4.15, and nut coal at $2.25 per ton. Which is the best to buy?

A. E. D.

A. We cannot give you any definite information as to which is the best grade of coal to use until we know more about the coal. We must know how much moisture, volatile matter and ash it contains in order to make a satisfactory statement as to its fitness for any type of setting. Also we should know the per cent of fines in each of the different grades you have mentioned. What are the specifications used in classifying these different grades? Is the coal put through a round or square mesh screen?

If it is typical Iowa coal with a high moisture content

and the nut coal does not have too high a percentage of fines, then considering only these three coals, we think it would be satisfactory to use this latter grade which, as stated, costs only $2.25 a ton, whereas the other grades cost $4.10 and $4.15 a ton respectively.

In buying any coal in large quantities, particularly for municipal plant operation, the purchaser should insist on a proximate analysis and perhaps a B.t.u. value of the coal. We do not believe it advisable, except on special occasions to buy coal on a B.t.u. basis but we do believe it advisable to buy coal on the basis of a proximate analysis. This gives a better indication of the adaptability of the characteristics of the coal to a particular setting than does a mere statement of B.t.u.

Apparently you have a normal setting for a 150-hp. return tubular boiler but even with this setting height and with a boiler of this type, the use of coal having a high percentage of volatile matter may cause excessive smoke, unless the firing is done by an expert.

Hand firing Pocahontas, Georges Creek, or some other grade of eastern coal containing a low per cent of volatile matter, would give better results than using midwestern coals which have high volatile and high ash contents. These eastern coals cost more but sometimes the increase and efficiency in output may more than pay for the increased cost. This question cannot be decided without detailed information.

Maximum CO_2 Obtainable from Fuels

In the June 1 issue, p. 667, under the above heading, C. W. Stevens has reopened the question of the maximum possible CO_2 obtainable from fuels and in this connection a study of the possibilities with a high oxygen content fuel are of interest. A representative ultimate analysis of a wood fuel is as follows:

	Per cent
Carbon	50.31
Hydrogen	6.20
Oxygen	43.08
Ash	0.37
Nitrogen	0.04
	100.00

Hydrogen and the oxygen are present in about the proper proportions for combination into water but a considerable portion of the hydrogen is unoxidized, leaving some 17 per cent of free and uncombined oxygen. It is to be noted that this oxygen is not accompanied by the usual nitrogen of air and this opens the way for some unique results more especially since the oxygen in this instance has a greater affinity for carbon than it has for hydrogen.

Under normal combustion conditions the dry products of combustion of the wood fuel represented above are as follows:

	— Per cent —				
Excess air	0	20	40	60	80
Carbon dioxide	20.1	16.7	14.3	12.5	11.1
Oxygen	0	3.5	6.0	7.9	9.3
Nitrogen	79.9	79.8	79.7	79.6	79.6

It will be noted that, due to the presence of the oxygen, the fuel is ranked close to a pure carbon fuel, having a maximum possible carbon dioxide of 20.1 per cent even though the hydrogen-carbon ratio would place it near the average fuel oil with a maximum possible carbon dioxide of somewhat under 16 per cent.

Wood refuse fuel is often burned with a moisture content of upward of 50 per cent. This requires a dutch oven type of furnace with a large area of reflecting brickwork. Such an oven when it is in good condition will permit the combustion of the fuel with a percentage of excess air not exceeding 15 per cent. The average carbon dioxide of the dry products of combustion will then be in the neighborhood of 18 per cent but local samples of from 23 to 25 per cent carbon dioxide can be obtained due to distillation effects and the greater affinity of the carbon of the fuel for the free oxygen of the fuel.

In order to verify the above, some tests were conducted with a small experimental furnace. The furnace was brought up to a good heat and the air dampers were closed, permitting the combustion of the fuel with a small amount of air. Depending upon furnace temperature, available air for combustion, and lapse of time after firing, the following Orsat determinations were obtained:

Per Cent		
CO_2	O_2	CO
10.0	17.0	4.0
22.0	13.0	9.0
42.5	7.5	17.0
56.6	0.8	38.6

All standard precautions to insure Orsat accuracy were observed. Approximately one-half of the determinations for carbon dioxide were checked with parallel absorptions in N/10 KOH solutions which were later analyzed in duplicate by two standard titration methods. The Orsat carbon dioxide determinations invariably were higher than the titration determinations, the excess ranging from 1.0 to 6.5 per cent. An unsuccessful attempt was made to account for this discrepancy which was quite regular.

It is, of course, understood that the foregoing freak readings are not due to normal or efficient combustion. The writer has, however, on a number of occasions while conducting efficiency tests, obtained carbon dioxide readings with wood fuel that ranged from 20 to 25 per cent.

Powell River, B. C. M. S. Gerend.

Receiver Pressure for Compound Engine

What is the proper receiver pressure for a cross compound engine, operating either condensing or non-condensing? L. L. H.

A. For condensing operation, the receiving pressure should be approximately the absolute boiler pressure divided by the cylinder ratio. Thus, if there is a steam gage pressure of 150 lb. or approximately 165 lb. per sq. in. absolute and a cylinder ratio of 5 to 1, the receiver pressure should be about $165 \div 5 = 33$ lb. per sq. in. absolute or about 18 lb. per sq. in. gage.

For non-condensing operation, the receiver pressure should be approximately the geometric mean between the absolute inlet pressure and the absolute back pressure. The geometric mean between two values is the square root of their product. Thus, if there is a line pressure of 165 and a pack pressure of 20 lb. per sq. in. absolute, the receiver pressure should be $\sqrt{20 \times 165} = 57.4$ lb. per sq. in. absolute or about 42 lb. per sq. in. gage.

Condensate from the World's Power Plant

ANALYZED FOR QUICK STUDY AND COMPARISON. BY WILLIAM SIBLEY

Power Plant Electric Output a Business Indicator

Recently, Arthur Williams, vice-president of the New York Edison Co., expressed the opinion that consumption of electric energy indicates, in a large measure, the condition of general business and even predicted that the kilowatt-hour output of central stations would soon take its place with car loadings, unfilled orders for steel and like industrial factors as one of our most reliable business barometers.

Electricity is of such universal use that it enters into all industry and to a large degree into many particular industries. It is the prime mover for communication and for much transportation. So that the extent to which it is used shows the trend of commercial activity.

As 86 per cent of the electrical energy used in the United States is produced from public utilities, it would be easy to compile accurate figures as to production and consumption and even to analyze this into amounts used by the various industries. In fact, the National Electric Light Association has now available most of the data needed. In 1920 the output was 39,519,129,000 kw-hr. which dropped slightly in 1921 but recovered in 1922 and has since advanced steadily to over 61,000,000,000 kw-hr. in 1925. Bank clearings show the same trend over these years.

Since all purchased power is metered and varies with the activity and production of the plant using it, record of electrical energy purchased by each industry would give a clear picture of the activity in that industry, to the extent to which it buys current and the percentage of electrification in the various industries is quite well known.

It is desirable to stabilize, as far as possible, business activity so as to avoid booms and panic. The Federal Reserve System has been of great help in this regard but every business indicator which will enable executives to plan wisely for the future is of assistance in avoiding over expansion and stabilizing industrial activity.

All Industries Are Interrelated

Because at no previous time have the various divisions of industry been more completely dovetailed or interlocked, knowledge of existing conditions in "extraneous" fields has never been more imperative. A few years ago manufacturers evinced little interest in the growth or decay of another business or industry. Today such apathy is likely to result in self-annihilation.

On the commutation train the other day we became involved in conversation with two men, one of whom was interested in meat packing, the other in coal. The meat products man, thinking to "get a rise" out of his coal friend, said: "Well—when is the oil industry going to put you out of business?" Mr. Coalman immediately started a tirade against both fuel oil producers and consumers. Whereupon we asked the coal man: "Don't you sell coal and coke to the oil industry?" "Certainly not," came the answer. "They use their own fuel of course." Turning to Mr. Meatman, we ventured: "You sell the oil industry, of course?" "Why—not that I know of. They don't use our products do they?"

"Only about 24,000,000 gal. of animal oils a year—worth about $18,000,000" was the reply. Then turning to the coal man, we suggested that he get acquainted with the oil men since they annually required more than 6,000,000 t., or well over $20,000,000 worth of coal.

Our experience with these two men, both of whom were capital fellows but who were so wrapped up in their own businesses and so completely absorbed by immediate sales and production problems and circumscribed by industrial prejudice as to have lost their proper perspective, reminded us of the West Virginia clay pit owner who made cheap brick and a poor living because he didn't know his clay was exceptionally well fitted for de-inking paper and was much in demand by certain mills in the paper industry; of the South Dakota brewer who completed a $1,250,000 brewing plant just 7 mo. before the advent of prohibition; of an entire sash, door, and millwork association which, in convention assembled, refused to approve a national advertising campaign, in spite of the fact that steel, concrete and synthetic products has already made heavy inroads into their business as exemplified by the 19-story St. Luke's Hospital in Chicago, in which there is not a stick of wood to be found, either in construction or equipment.

Every industry today is affected, by every other industry. The sugar industry is tied inseparably to agriculture, not solely in the matter of cane or beet, but in wheat, corn, sunflower seeds, and other grains, since today those grains are being made to yield high quality sugars. The fruit industry is a brother to the chemical industry since it has been found that prickly pears and other fruits can be made an economically profitable source of alcohol. The leather field and fisheries are now first cousins because sharks and porpoises are yielding their hides for the manufacture of high-grade leather. The timber interests and oil refineries have much in common, since gasoline is now made from eucalyptus trees. The manufacturing confectioner needs to know what the California or Florida fruit growers are doing, if for no other reason than that the public has but one stomach and, if that stomach is more nearly filled with raisins and oranges, there will be less room for candy.

Products may be different but never unrelated. For this reason "extraneous" is an obsolete term in industry, and knowledge of the existing trends and welfare of all branches of commerce is becoming increasingly necessary to every business man or manufacturer.

Lumber Singing Its Swan Song

In spite of the unprecedented building activities during and after the war, the output of lumber has steadily decreased since 1906. This fact was ably brought out in President Coolidge's recent address before the Forestry Conference in Washington. At that time he also called attention to the fact that with only 745 billion cubic feet of lumber in existence, our annual consumption is in excess of 25 billion cubic feet. Thus the demand far outstrips replenishment, which is about six billion cubic feet a year,

and brings the end of lumber as a staple commodity within the bounds of accurate calculation.

The lack of an adequate supply of lumber, with consequent prohibitive prices for the remaining stock, has brought about more durable and fire-resisting types of structures. The one time "lumber yard" has changed to a "building material supply yard" and, with that transition, the fire-inviting cedar shingle roofs have given way to fire-resisting asbestos, slate or tile roofs. Steel has replaced wood in nearly everything from bridges to office desks, with the dual result of greater durability and increased economy. The nineteen story St. Luke's Hospital, Chicago, with a capacity of over 500 beds, doesn't have a stick of wood in it, either in construction or equipment—with the result of greater safety from fire.

In the matter of prices, sheet steel, metal lath, steel rafters, and metal furniture is now on much the same plane as wood. The balance will soon be in favor of the former by reason of the growing scarcity of timber. Lumber is singing its swan song.

"Come on Up"

On the bulletin board of a large manufacturing company in Chicago appears the following which we believe worthy of republication here:

"Look back over 1925. Be honest with yourself. Did you endeavor to give the boss, at all times, just a little more than he paid for or expected? Did you make a real effort to learn more about the business that you might be more valuable to the business and yourself? Did you do any outside studying in preparation for the next step up?

In this organization we pay not for what an employe knows but for what he does. We pay not for what is in your head but for what comes out of it. Production or results is the sole measure of your ability and your compensation is based on what you have done. Just as soon as you do more, you will earn more.

Your department head, or your foreman, has no fear that you will "get his job." He is afraid you won't. He knows that when you push him out of his job you simultaneously push him up the ladder. It is to his interest to find and keep men who can "get his job."

We must constantly seek new fields—new markets. We are constantly searching for new methods that will reduce our production costs. The officers of this company have a lot of work to do. We need help—good help. Come on up."

Air Mail Facilitates Business

When a faithful, courageous air mail pilot crashes against a mountain side, is forced down by a storm or loses his life in the line of duty, we all hear about it. We shudder and wonder whether the air mail is as reliable as transcontinental mail trains.

Both services are essential to American business. The fastest trains carry busy executives to whom time is of great importance in their plans. When rapidity is not the first requirement, the slower trains serve for the greater number. The same conditions apply as between air mail and mail trains.

As to reliability check up shows that lateness of air mail is no more frequent than of train mail. Saving of time from Chicago to New York is some 7 hr., over the fastest trains and from Chicago to San Francisco about 2 days. During a recent blizzard, important mail trains to New York were running late but the air mail arrived ahead of time, utilizing sleds from the landing field in New Jersey and stopping a fast southern express to carry the mail on to New York.

For a pioneering and to a degree experimental service, the Transcontinental Air Mail has had, for the past year, a high percentage of on time arrivals, closely approximating and in many instances exceeding that of mail train on time arrivals. This in spite of a severe winter with frequent snows, fogs, blinding rain and sleet. The courageous, faithful and competent pilots have developed a skill in getting through and an endurance far greater than was called for in the quick dashes and daring exploits in France. When one of these valiant pioneers drops by the wayside he should have our heartfelt condolence, but he fell in the line of duty, a fate common to all industry, and carrying the mail by air has now developed into a routine job which is growing in volume. Non-delivery of the air mail is a rarity and its use is a fixed item in the mailing schedules of many of the biggest users and recipients of intersection and transcontinental mail. This convenience is well worth taking advantage of for every business according to its requirements.

Paying Workers—Cash vs. Checks

Since the introduction of the present day banking system, a large number of firms have adopted the check system when making up the pay-roll and paying employes. In the past there has been discussion, as to just which method possessed the greatest merit. This difference of opinion impelled the National Industrial Conference Board to send a questionnaire to over 100 of its members, the results of which are interesting.

Adherents to the check system claim that their method is the more reliable on the grounds of efficiency and protection. Briefly outlined, their opinions are:

1—No question as to the amount in the envelope.
2—Requires less clerical force in cashier's office.
3—Provides a permanent receipt for payment.
4—Affords more confidential handling of pay-roll.
5—Eliminates hold-ups.
6—Encourages employes to open bank accounts.
7—Promotes the thrift idea.
8—Protects employe against loss of pay envelope.

Those favoring the payment of wages in cash voiced the following disadvantages with the check system:

1—Checks always liable to forgery or raising.
2—Extra work by executives in signing checks.
3—Many employes prefer cash.
4—Inconveniences employes in getting funds readily.

The recent research found that more than half of the organizations who had tried the check system pronounced it satisfactory and expressed their intention to continue the practice. Several large industrial companies expressed the belief that the third objection to the checking system could be ironed out through a little education and coaching by the management.

Whether one system or the other is favored by the management is of little consequence compared with the importance of developing thrift and rational living among workers. In this regard, the consensus of opinion seems to favor the checks.

EDITORIAL COMMENT

What Is Critical Speed?

For a long time, in talking about the critical speeds of shafts, we have been in the habit of making the assumption that all rotating shafts carrying wheels or disks have a definite speed at which they will "whip" or vibrate and at which they may break. The general theory of critical speed is embodied in the formula $W_c = \sqrt{K/M}$ in which W_c is the angular velocity in radians per second, M the mass of the disk and $K = 48\ EI/l^3$, this value of K being derived from the general deflection formula $P = Ky.$, the weight of the shaft being negligible in comparison to the disk. This law becomes extremely complicated when applied to a shaft carrying several disks, which may have several critical speeds.

As the result of a long series of experiments, however, on the actual behavior of heavy rotors such as those used in large turbo-generators, it has been found that they do not follow closely the common theory of critical speeds. In fact, it has been found that they can be so well balanced, especially when running in journal bearings, that they can be run indefinitely at their critical speeds, as calculated by the usual methods, without serious disturbance. At the same time, there will be certain definite speeds, usually lower than the calculated critical speed, at which they will vibrate in either the vertical or the horizontal plane. For this reason, it was necessary to extend the commonly-accepted theory to cover this phenomenon. In short, this vibration has been found to be, in the case of a heavy rotor, a phenomenon of resonant vibration.

Elsewhere in this issue, a complete and unusually interesting discussion of the way in which the theory of critical speeds has been modified in the case of heavy rotors is given by Burt L. Newkirk. He explains the general theory and shows how the better balancing of such rotors, the effect of the deflection and the resisting forces, the effect of the bearings, the elasticity of their supports and other factors combine to affect their behavior. It is not to be understood that this explanation "overthrows" or "revolutionizes" our conception of critical speed. A shaft of negligible weight, carrying a heavy disk which cannot be perfectly balanced, probably adheres closely to the law. But with a turbo-generator rotor, having a shaft of large mass and diameter in proportion to the bucket wheels and generator coils it carries, the theory must be extended.

This article by Mr. Newkirk is of importance from several viewpoints. In the first place, it is a splendid illustration of the fact that we must keep constantly revising our conceptions of why things are as they are, whether we are dealing with an atom, a man or a turbo-generator. Second, it is one of the finest examples we have seen of a technical explanation, made in a clear, logical manner and without the use of abstruse mathematics, which the reader can follow and from which he can actually visualize what takes place. Finally and most important of all, it gives us an entirely new conception of what actually happens when a heavy rotor is revolved, it shows the reasons for this behavior and—of especial interest—it tells how the behavior of a given rotor can be predicted with considerable accuracy. The value of the latter knowledge to all those who design, build and operate turbines is so great that it cannot be measured in any way by the money and effort spent in getting it.

War on Mosquitoes

Most power plants are built in lowlands, near rivers, lakes or bays and in many cases swamps or stagnant pools of water are also nearby. Where such conditions exist, mosquitoes are sure to be found, as many power plant operators, no doubt, can testify.

Aside from the discomfort which they cause, mosquitoes are positively dangerous and their bite frequently causes disease. Power plant engineers generally are sold on the idea of safety first and will even go out of their way to pick up a board with protruding nails but fail to attach any significance to a shallow depression or sump in the ground which contains water. Time and again mosquitoes have been known to breed in large numbers even in water-filled tin cans found on dumps.

All mosquitoes are hatched from eggs and, despite stories to the contrary, they do not breed in damp shrubbery or dew, but only in water. They pass the first stages of their existence in water and finally emerge fully grown.

Every year in the United States mosquitoes cause 3,000,000 cases of malaria and take more than $100,000,000 from the nation's pocket book as a result. Only female mosquitoes feed on blood. Male mosquitoes live only on plant juices and never bite animals or men.

When Dr. Carlos Finlay, of Havana, in 1881, first suggested that yellow fever was transmitted from man to man by the bite of a certain mosquito, he was laughed at. Twenty years later the Walter Reed Board proved he was right. All the world now knows of the great work which the late Gen. Gorgas did in both Havana and the Panama Canal zone in eradicating yellow fever, dengue fever, and malaria. He drained the swamps and, in thus destroying the breeding places of mosquitoes, he prevented the transmittal of disease.

Gen. Gorgas saved 71,000 lives and $80,000,000 during the construction of the Panama Canal and what he did in the heat and floods of a tropical country, naturally more favorable for mosquitoes, surely we ought to be able to accomplish in this temperate climate.

In Chicago, the Gorgas Memorial Institute is carrying on the great work of the man for whom it is named and expert advice on mosquito eradication is given on request.

Some people think that the larger the body of water or swampy area, the more mosquitoes it can produce. In many cases, however, ponds with clean edges produce

few mosquitoes because the fish have access to the larvae that might develop there, while isolated pools close to the pond that contain no mosquito enemies may produce large numbers.

Drainage and admittance of sunlight into damp, shaded places is the best method of mosquito eradication. Oil spraying is not permanent and must be repeated frequently. It should be adopted only where drainage is impossible or impracticable.

Off Duty

Considerable prominence has been given by newspapers during the past few months to reports of icebergs drifting in the north-Atlantic steamer lanes. Icebergs, it appears are more numerous this spring than usual and naturally constitute a serious menace to shipping. These reports have created some discussions and several individuals have offered the suggestion that the government blow up the icebergs with high explosives.

Coming from those who have never seen an iceberg this suggestion is, no doubt, logical and, with the average person's unbounded faith in modern human accomplishment, practical; unfortunately, however, it does not take into account the size of an iceberg. Icebergs, as a rule, weigh over 50 lb. Imagine, if you can, a chunk of ice a city block long, towering some 250 ft. above the surface of the ocean. Beneath the surface, now imagine a mass of ice, seven times as great as that above the water—a million and a half tons of ice! Now you have a working idea of a good-sized iceberg. Blow it up? To think that dynamite or TNT could more than scratch the surface of such a mass is sheer folly.

Yet, it has been tried. As described in the current issue of the National Geographic Magazine, the U. S. Coast Guard cutter Tampa, in the spring of 1925 made several unsuccessful attempts to destroy icebergs in this manner. True, in the case of a small berg showing 10 ft. above the water line they succeeded in cutting off two days of its life, but with a larger berg, 300 ft. long and 150 ft. above the water the effects of high explosives were absolutely negligible. With some 200 lb. of TNT, the berg merely shivered, a geyser of water and smoke went up 100 ft., settled back again and all was calm. No damage whatever.

In this manner, nature often takes the conceit out of us humans. We pride ourselves in being clever and our success in solving some of nature's mysteries and in overcoming a few of the minor obstacles which she has placed in our way, at times permits our egotism to get the best of us. Then we try to blow up icebergs!

We talk glibly about harnessing the forces of nature and merely because we are able to build a dam across a river or cut a canal through 50 miles of rock, we actually come to believe in our powers over nature. Great cities of steel and stone rising under the magic hand of engineering and huge airships defying gravity strengthen this belief. We look around, and viewing our achievements write ponderous histories showing how we, the product of centuries of civilizing influence, under divine guidance, of course, have been selected to rule this planet. Truly, we must be of great importance in this universe.

Along comes nature in a playful mood, shakes a portion of the earth's crust back and forth three-quarters of an inch and, Presto! the cities which have taken centuries in the making crumble to ruin in ten seconds; the dams which impound hundreds of acres of water collapse, and the canals which have cost thousands of men years of labor vanish in the flash of an eye. A moderate thunder storm catches our giant airship costing millions of dollars, twists it around a couple of times, and a moment later tosses it to earth, a shapeless mass of tangled wreckage. A said-to-be extinct volcano becomes tired of her surroundings so she lights up, blows a couple of hundred million tons of molten rock into the air and changes the character of the landscape somewhat, incidentally, snuffing out 30,000 lives in a neighboring city.

Man is in the habit of interpreting nature only in terms of his own limited knowledge and experience. At one time he thought, and many still think so, that nature provided the sun, (which could contain a million earths) only to light up this miserable speck of rock we call the world, and the world he thought came into being only a few years before a time back to which his memory extended. It was, furthermore, created for his especial benefit. But the astronomers and the geologists, reading nature's own handwriting found a different story—a story which man is loath to accept because of his own trivial part in it.

Indeed, his colossal egotism was rudely shaken before the procession of the ages. Aghast, he discovered that the billions of years which produced this earth from star dust was not merely nature's laborious preparation of a habitation for so admirable an occupant, but that man, on the contrary, was nothing more nor less than the present master tenant of the earth—the highest type of hundreds of millions of years of succeeding tenants only because he was the latest in evolution.

Nature runs her course regardless of man, or for that matter regardless of anything man considers important. If the earth should be blown to pieces today and all life instantly blotted out, it would make not a particle of difference in the eternal scheme of the universe.

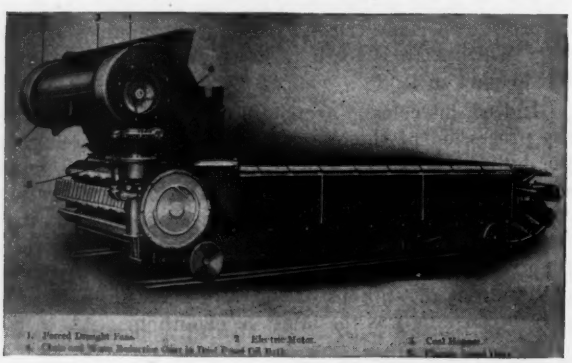
On the other hand, who can say that the day will not come when a race of human beings as superior to man intellectually and spiritually as man is superior to the ape will rule the world and who in that far distant day, from fossil fragments found in the sedimentary strata of new continents will endeavor to reconstruct a picture of prehistoric times which today are the present? These people will, no doubt, be exceedingly wise and will know all things, but, if they carry any of our blood in their veins, we have a sneaking suspicion, that they, too, will endeavor to blow up icebergs.

From August 31 to September 12 a sectional meeting of the World Power Conference will be held at Basle, Switzerland, which representatives of the American Committee will attend. As its contribution the committee announces that five papers will be presented: Utilization of Water Power and Inland Navigation by Col. Hugh L. Cooper of New York; Exchange of Electrical Energy Between Countries by Col. William Kelly of New York; Economic Relation Between Electrical Energy Produced Hydraulically and Produced Thermally by W. E. Mitchell of Birmingham; Electricity in Agriculture by Dr. E. A. White of Chicago; Railway Electrification by W. S. Murray of New York.

POWER PLANT ENGINEERING DEVELOPMENTS AND NEWS

Self-Contained Stoker Installed at Sears, Roebuck & Co.

FOR THE past few months Sears, Roebuck & Co. have been experimenting with the burning of Illinois coal on a new type of self-contained traveling grate stoker of English design, built by the Combustion Engineering Corp. at its East Chicago, Ind., plant.



THIS SELF-CONTAINED TRAVELING GRATE STOKER HAS FANS AND AIR DUCTS BUILT IN AS AN INTEGRAL PART OF THE UNIT. THE SAME MOTOR DRIVES THE FANS AND THE STOKER

This is the first stoker of this type to be built in this country. It was developed in England by the Underfeed Stoker Co., Ltd., and its success there resulted in its being built in this country.

In the accompanying figure is shown a side view of this new stoker. Its major advantage is that it permits the application of forced draft to existing natural draft plants where conditions prevent the expensive reconstruction involved in providing space for fans, drives and fan ducts and the reconstruction of furnaces.

In the design of this self-contained stoker the forced draft fans are mounted on the stoker frame and forced draft ducts also are part of the stoker structure. They extend along the side frames on either side and air is admitted to the underside of the grate surface by a special damper mechanism which graduates the supply from the front to the rear of the grate. These dampers are operated from the front of the stoker. In the position they occupy, the fans improve the ventilation of the boiler room. A current of air is induced towards the fans and removes the dust which is created at or near the hopper of the stokers; a clean boiler house is thereby insured. One motor drives both fans and stoker, each being provided with thorough regulation.

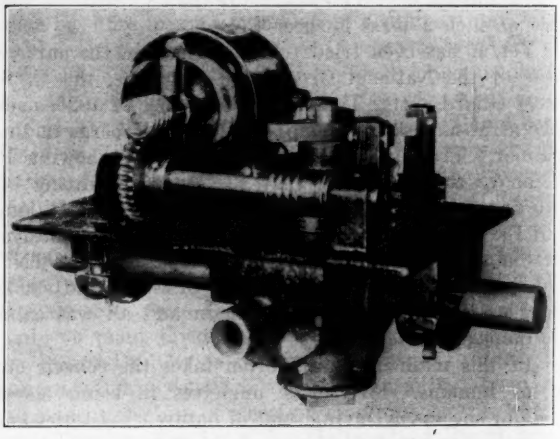
As may be seen in the accompanying illustration, the grate is composed of a series of box-shaped, sectional fire bars. These bars are mounted upon chains which engage the sprocket wheels.

The stoker may be removed from the furnace without having first to break joints with an air duct to disconnect any driving mechanism.

This stoker is adaptable to a wide range of fuels including non-coking bituminous coals, all kinds of anthracite coals, coke breeze and lignites. Although it may be applied to boilers of all sizes and types, it is ideally suited to boilers ranging up to 600 hp.

Small Motor-Operated Valves for Ammonia and Water Lines

TWO NEW motor-operated valves, one for refrigeration work and the other a pilot valve, have recently been placed on the market. The pilot valve was designed to control large hydraulically-operated valves,



MOTOR ACTUATES PILOT VALVE THROUGH REDUCTION GEAR, WITH PROVISION FOR REMOTE CONTROL

and the other valve is for use in an ammonia liquid line ahead of an automatic expansion valve for controlling the refrigeration of a room, box, counter or other enclosure.

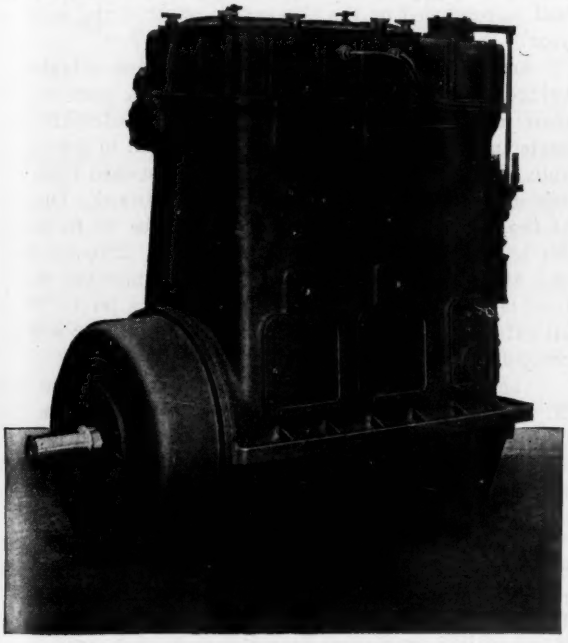
The mechanism of the ammonia valve is intended for thermostat control and this method is designed to cool a number of rooms by a single compressor, the opening and closing of the various valves responding to the action of their respective thermostats. The mechanism and valve are in separate units and the former is practically a device by itself. The valve is of the stop cock type with flanged ends and with packing around the stem. A compensating spring is designed to maintain even pressure between stem and seat. The driving

mechanism may be mounted on any type of valve and may, if desired, be used to provide a number of intermediate positions between open and closed. The mechanisms are at present being built for ½-in. and 1½-in. pipe.

The pilot valve was designed for the remote control of fire or similar hydraulic systems. It consists of a four-way cock suitable for water or other liquids under pressures up to 350 lb. A motor is mounted on the valve, together with a double worm reduction gear and a limit switch control. An open-close push button allows remote control. A 1/25-hp. G. E. motor is furnished for either direct or alternating current. Both of these valves have been placed on the market by the St. Louis Motor Valve Co., St. Louis, Mo., and are driven by General Electric motors.

High Speed Diesel Finds Wide Application

AS THE first commercial high speed Diesel to be manufactured in America, the Foos Gas Engine Co. of Springfield, O., announces its new Type L. Diesel,



FOOS HIGH SPEED TYPE L DIESEL

which is completely enclosed, the only moving part visible being the flange coupling.

Practically all mobile, semi-mobile and stationary requirements are met by the range of speeds and sizes offered. Ratings of from 50 to 475 hp. in from two to eight cylinders are developed at speeds up to 900 r.p.m. The engine is of the four-cycle, solid injection, full Diesel type and burns all low cost fuel oils commonly used in larger engines.

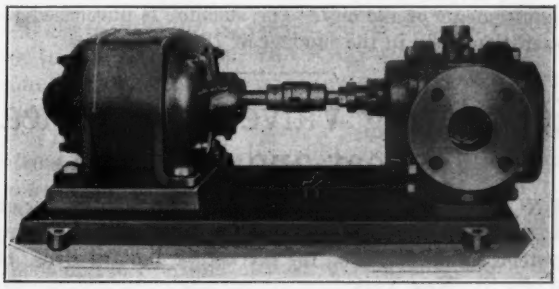
Pressure lubrication is used throughout and a separate fuel pump is furnished for each cylinder. Starting air at 250 lb. is required and an air valve placed on each cylinder. The crankshaft, forged solid, is supported in large bearings and balanced by counterweights. Low brake mean effective pressures are used in the nominal rating of the engine and the engine weight per horsepower varies from 30 to 60 lb.

All parts are protected against dirt and dust by the housing which effectively muffles sounds of operation and confines the lubricating oil spray and vapors. Large cover plates allow ready access for inspection, or adjustment, of any and all parts, all elements being independently removable without disturbing other parts.

Accurate regulation is an important feature, while the fuel economy, substantial construction, conservative rating, high speed and small proportions will open up a wide field of application which heretofore has been considered beyond the scope of Diesel application.

Gear Pump Developed for High Speeds

IN ORDER to complete its line of low speed, spur gear pumps designed to handle oil and viscous liquids, the Schutte & Koerting Co. of Philadelphia, Pa., has recently developed a herringbone gear pump to handle lighter oils and liquids of non-lubricating character.



GEAR PUMP DEVELOPED TO HANDLE LIGHT OILS

Pumps of this kind can now be supplied in over 30 sizes, capacities ranging from ½ to 125 g.p.m. with a speed range of from 600 to 1800 r.p.m. These pumps are designed for direct connection to electrical motors or high speed engines as preferred; they are made in both standard and reversible types with or without a bypass.

Herringbone gears, carefully machined, are mounted on ball bearings to insure high efficiency with smooth and silent operation.

Hell Gate to Have 160,000-Kw. Turbo-Generator

ACCORDING to an announcement made recently by the United Electric Light & Power Company of New York, there is to be installed in the Hell Gate station a turbo-generator which will be the largest unit in the world. The order has been placed with the American Brown Boveri Electric Corp. and the installation is to be made under the supervision of Thos. E. Murray, Inc.

The new turbo-generator will have a rated continuous load capacity of 160,000 kw., or about 250,000 hp. It will generate current at 13,800 v., 60 cycles. The steam turbine will be of the reaction type throughout. It is designed to occupy the same space allotted to each of the other seven units now installed at Hell Gate and its in-

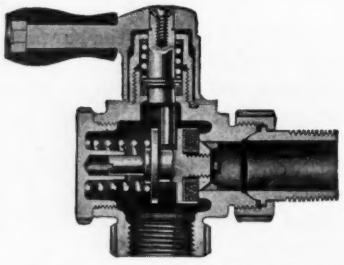
stallation will complete the equipment of the present station building. This will bring the station capacity up to 445,000 kw. The turbine will operate under the present steam conditions of the station, 265 lb. pressure at turbine throttle, with 200 deg. superheat, and is designed for bleeding steam for feed water heating. The high pressure turbine portion is designed to be capable also of utilizing steam at a maximum temperature of 750 deg. F. The unit will weigh approximately 2,800,000 lb. and the heaviest single piece will weigh 330,000 lb.

It is announced by the manufacturers that the unit will be set up at the Camden plant of the company and will be shipped to New York on ocean-going barges via the Atlantic Ocean into New York harbor and through the East River to Hell Gate station.

It is interesting to know that this machine will be capable of furnishing enough electric power to light up 1,000,000 homes in New York and, if the entire lighting system of the city were to go out of commission at one time, leaving only the newly ordered turbine as a buttress between the city and total darkness, it would be potentially able, single handed, to take care of the entire street lighting and three-quarters of the home lighting requirements of the city. The machine is purchased for operation early in the summer of 1928.

Regulating Valve Has Vertical Seat and Disc

INCORPORATING several important features a new modulating regulator valve for low pressure heating systems has been put on the market by Jenkins Bros., 80 White St., New York.



CONSTRUCTION OF VALVE IS SHOWN CLEARLY IN CROSS SECTION

This valve, which will be known as their Fig. 700, has the valve and seat in a vertical plane to prevent lodgment of scale and core sand on the seat as well as eliminate gurgling and water hammer.

Leakage around the spindle is prevented by a composition ring and compression spring. The handle of red Bakelite moves a half revolution to open or close the valve by means of a cam, the Off and On positions being clearly indicated on an indicator dial.

Hexagons on the body and union have been replaced by beads, or ribs, conforming to the grip of a pipe wrench to prevent marring and cutting during installation. Dimensions conform to the recommendations of the Heating and Piping Contractors' National Association and to the Manufacturers' Standardization Society.

Construction Begun at Conowingo Hydro-Electric Plant

SECOND ONLY to the plant of the Niagara Falls Power Co. and surpassing Muscle Shoals, will be the Conowingo hydro-electric plant which is being built by Stone and Webster, Inc., for the Philadelphia Electric Power Co. on the Susquehanna River, within 4 mi. of tidewater in the state of Maryland. A dam 4800 ft. long—300 ft. longer than the Muscle Shoals dam—is being built across the river to form a reservoir of 8100 acres. Power generated will be sent over high voltage transmission lines into Philadelphia, 75 mi. away.

Ultimately this hydro-electric station will contain 11 generators, each rated at 50,000 hp., or 36,000 kw. The initial installation will include seven of these units, giving the station 350,000 hp.; the Niagara Falls Power Co. development produces 452,500 hp., and Muscle Shoals 260,000 hp. Four of the waterwheel-driven generators for Conowingo are now being made by the General Electric Co. They are rated at 40,000 kv.a., 90 per cent power factor, and 13,800 v., with a speed of 81.8 r.p.m. It is expected that 1,360,000,000 kw-hr. of energy will be produced by the Conowingo plant in the average year.

Across the top of the dam there will be a highway bridge, 105 ft. above the foundation, as a part of the main highway between Baltimore and Philadelphia and replacing a bridge which will be submerged in the reservoir. The spillway section will extend eastward from the center of the dam; the power house westward. On top of the spillway, the crest of which will be 86 ft. above sea level, will be 50 movable steel gates, 22½ ft. high and 40 ft. wide. These gates will maintain the water level behind the dam at 108½ ft. above sea level. With all gates open, the discharge rate of the spillway will be 880,000 cu. ft. per sec.

The power house itself will be 175 ft. wide and 620 ft. long, with an ultimate length of 900 ft. From the bottom of the draft tubes to the top of the high tension switching station on the roof it will be 230 ft. high. In this connection, it is interesting to note that the bottom of the draft tubes will be 25 ft. below sea level.

Power produced by the generators at 13,800 v. will be stepped up to 220,000 v. by transformers and at this pressure sent over two transmission lines to Philadelphia. Each line will have sufficient capacity to carry the full load in case of trouble with the other one. When the final four generators are added to the power station, a third transmission line will be constructed.

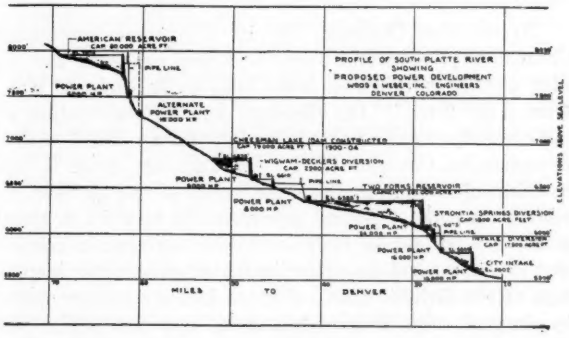
The Conowingo hydro-electric development will be co-ordinated with the great steam-turbine generating plants of the company so that the water power will be used to supply the base load of the system when the flow of the river is ample, and the steam stations to supply the peak load. When the river flow is low, the steam stations will be used for carrying the base load, and the water power will be called upon only for peak loads. When the river flow is sufficient for full operation, Conowingo will supply 231,000 kw. for base load; when the river is low, the enormous reservoir will be called upon, and staistics covering a period of 35 yr. show that, in the driest period of the year, Conowingo will be able to supply 190,000 kw. for peak loads.

Denver Plans Hydro Development on South Platte

BY THE MAKING public of a report prepared by Wood & Weber, engineers of Denver, for a group of prominent citizens concerning the power possibilities of South Platte River above Denver, a great deal of interest has recently been aroused. Although all the details of the project have not been made public because of certain policies that must be established, many of the basic data are available.

About 25 mi. above the city intake is located what is known as Cheesman Dam, which impounds about 79,000 acre-ft. of water. At the present time this is the main storage reservoir for city purposes and is over 1200 ft. above the city intake. At present the stored water from Cheesman runs down the open channel of the river to the city intake.

In brief, it is proposed to build Two Forks Dam about 325 ft. high to impound 262,000 acre-ft. of water and American Dam to impound 80,000 acre-ft. of water.



DIAGRAMMATIC PROFILE OF PROPOSED DEVELOPMENT ON SOUTH PLATTE RIVER

These two with the present Cheesman reservoir form three major reservoirs, as shown in the diagram. From American site down to city intake the river falls about 2300 ft. It is proposed to use about 1600 ft. of this entire fall to generate power for use in and around Denver. In order to keep away from long pipe lines, it is proposed to build three minor dams, impounding a small amount of water but acting chiefly to create the head for power generation so that long pipe lines will not be needed. Below each of these dams will be located a power plant consisting of water wheels and generators of the proper type and size. Data for the various units will be found in Table No. 1. The various plants will be connected with a 100,000-v. transmission line running into a substation on the outskirts of Denver, where the current will be stepped down to the proper voltage for use.

Two Forks will be the principal station and will be manually operated and will be the master operating station for all of the others.

Criticism has been directed against the project because of the general supposition that the runoff of the river is not sufficient to supply the needs of the plants as planned. The most careful checking and routing of water according to stream flow measurements during the past 20 yr., however, indicates that there is sufficient water to generate the amount of power indicated in the report.

At the present time an attempt is being made to sell the power to The Public Service Company of Colorado, which supplies Denver and surrounding territory with electricity. The price proposed will average about eight mills a kilowatt-hour delivered on the low tension side of the transformer substation in Denver.

If this fails to produce results other plans may be adopted for disposing of the power, to some other company or to the city as a municipal enterprise.

TABLE SHOWING STORAGE AND POWER CAPACITIES OF UNITS IN THE DEVELOPMENT

Dam	Capacity Acre Ft.	Standing Head Ft.	H.P. Installed	Units	Control
American	80,000	417	6,000	2	Automatic
Cheesman	79,000	225	9,000	3	Automatic
Wigwam - Deckers	2,900	225	8,000	2	Automatic
Two Forks	262,000	312	24,000	3	Manual
Strontia Springs	1,800	253	16,000	2	Automatic
Intake	17,500	210	16,000	2	Semi Automatic
TOTAL.....	443,200	1662	79,000	14	

Careful estimates indicate that the entire cost, excluding Two Forks Dam, will be $12,500,000. Whether the electric project is constructed or not, the city will be forced to construct Two Forks Dam some day for municipal water supply purposes, so it may be that this dam will be constructed by the city. Nevertheless, if it is finally so decided, the Two Forks Dam will be constructed as a part of this project at an additional amount of around $5,000,000, making the total cost $17,500,000.

Much interest has been aroused by the announcement of the proposed method of financing, which is by income bonds or debentures.

A group of bankers, headed by James H. Causey & Co., of Denver, has agreed to take the income bonds. The Fargo Engineering Co. of Jackson, Michigan, working with Wood & Weber, has agreed to take a contract to build the project for the estimated cost. Wood & Weber, Inc., engineers of Denver, have made all of the preliminary investigation and designs.

President Coolidge Starts Merced-Exchequer Hydro Plant

ON THURSDAY, June 24, at 11 o'clock, President Coolidge pressed a button in Washington that set in motion the generating units and formally dedicated the 42,000-hp. hydro-electric plant at the Merced-Exchequer Dam, the highest dam in the world, located on the Merced River, Merced County, Calif.

When the President touched the key which closed the circuit in the power house below the dam, two turbines, capable of generating 42,000 hp., whirred into action. At the same moment, a 5-gal. glass container filled with Merced River water was dropped from the top of the dam to the concrete roof of the power house, a distance of 300 ft. As the glass container dropped through the air with red, white and blue streamers whipping above it, 1500 spectators began a cheer which reached a shrieking crescendo just as the container dashed into a thousand pieces on the roof of the power house.

The spectators then climbed to the top of the dam, 330 ft. above the level of the Merced River, to listen to the orators and to congratulatory messages from President Coolidge, Secretaries Hoover, Jardine and Work, and others.

Caustic Embrittlement Proved as One Cause of Cracks

AT A RECENT meeting of the American Society for Testing Materials held at Atlantic City, N. J., a paper entitled "The Cause and Prevention of Embrittlement of Boiler Plate" was presented by S. W. Parr and F. G. Straub of the University of Illinois. This paper prefaces a more complete report on the subject which is soon to be released by the Engineering Experiment Station of the University of Illinois as Bulletin No. 155. A thorough abstract of this bulletin will appear in Power Plant Engineering.

Mr. Parr, who is professor of Applied Chemistry at the above university, has been engaged in research on this subject for many years. Results of his latest research now make it possible to recognize embrittlement cracks when met with.

There are three distinctive types of cracks: first, those due to direct corrosion; second, due to fatigue; and third, those which are caused by caustic solutions.

A method of procedure was devised whereby the embrittlement effect could be produced at will, thus making it possible to study both the conditions under which it occurs and remedies for its prevention. The results indicate that two conditions must be present simultaneously to produce the embrittlement effect: first, the stressing of the metal above the yield point; and second, the concentration of sodium hydroxide to a point which is in excess of 350 g. per liter. Parallel tests omitting the sodium hydroxide show no effect. Tests upon various types of metal from the purest obtainable to those with a high percentage of impurities show that impurities do not modify the conditions.

Inhibition of embrittlement, as indicated by the experiments as far as they have gone, might be accomplished by the elimination of localized stresses, which is assumed to be impossible. The modification or control of the chemical condition of the water has been found to be effective. Data on actual plants in use, covering a period of ten years, are consistent with the artificial embrittlement in that by maintaining a ratio of sodium sulphate to sodium hydroxide in excess of 2, no embrittlement is found to occur. Free sodium carbonate in the water is in itself not active in producing embrittlement, but contains a potential danger in that it gradually is hydrolized into caustic form.

THE SOUTHEASTERN POWER & LIGHT CO., Birmingham, Ala., is completing negotiations for the purchase of the Georgia Railway, Light & Power Co., Atlanta, and the Athens Railway & Electric Co., Athens, and will operate them in conjunction with its other power properties. The first noted Georgia company also controls the Macon Railway & Light Co., Macon Gas Co., General Georgia Power Co., and the Central Georgia Transmission Co. Transmission lines will be extended. Thomas W. Martin is president.

News Notes

AT ITS MEETING of June 23, the Federal Power Commission, Washington, D. C., voted to authorize the issuance of a license for 25 yr. to Emma Rose, Anna G. Lane and Hobart Estate Co., of San Francisco, for a project on Highland Creek in Tuolumne and Alpine Counties, Calif. Power proposed to be developed will be used in mining and public utility service. The commission also issued license to East Bay Municipal Utility District of Oakland for a proposed power project to consist of a dam known as the Lancha Plana Dam, a reservoir, a power house equipped with two 5000-hp. generating units, and a transmission line about 82 mi. in length.

License was also issued to the Illinois Northern Utilities Co. of Dixon, Ill., for a proposed development in Rock River near Byron. Here it is proposed to construct a reinforced-concrete dam with earthen embankments, with an estimated storage capacity of 1100 acre feet. The power house will be integral with the dam, with an installed capacity of about 1600 hp. for public utility purposes.

MILWAUKEE COUNCIL NO. 19, Universal Craftsmen Council of Engineers, announces the program for its 24th annual convention, to be held in Milwaukee, Wis., from Aug. 2 to 7. On Monday, Aug. 2, registration of the delegates will be held at the Republican Hotel, with a reception in Colonial Hall. On Tuesday, Aug. 3, the mechanical exhibit in the main arena of the auditorium will be opened. Opening exercises will be held at 10:00 a. m., in Convention Hall; a regular convention session at 2:30 p. m. and a smoker in the evening after inspection of the Exhibit Hall. For the ladies a theatre party is planned. On Wednesday, Aug. 4, a convention session will be held at 9:30 a.m., and in the afternoon automobile trips will be taken to places of interest, while an exhibitors' entertainment will be held at 8:00 p.m. at the auditorium. On Thursday, Aug. 5, after the morning convention session, delegates will visit the Nordberg plant, Lakeside Power Plant and the plant of the Milwaukee Journal. A memorial service will be held at noon on Friday, Aug. 6. In the evening the regular banquet and entertainment will be held.

G. H. BUCHER, Assistant General Manager of the Westinghouse Electric International Co., has announced the election of Charles V. Allen to fill the position of treasurer and assistant secretary, recently left vacant by the resignation of H. A. Carmichael.

UNDER THE LAWS OF THE State of Illinois, a sales company has just been formed to be known as Joseph Harrington Co., a subsidiary of Whiting Corp., for the purpose of marketing the "King Coal" stoker. This stoker was especially designed by Joseph Harrington for small boilers of 40 to 250 rated horsepower, and particularly for entirely automatic operation with horizontal return tubular boilers. Officers of the new company are Joseph Harrington, president; T. S. Hammond and R. H. Bourne, vice presidents; R. A. Pascoe, secretary-treasurer. The general offices and works will be at Harvey, Ill.

HILLS-MCCANNA CO., Chicago, announces the opening of its eastern sales office, in charge of F. R. Glenner, at Rm. 704, 53 Park Place, New York City.

GRINDLE FUEL EQUIPMENT Co., Harvey, Ill., announces that it has retained Joseph Harrington to act as advisory engineer in connection with the application of Grindle pulverized coal equipment to steam boilers.

R. H. BAKER Co., INC., Cambridge, Mass., contractor for power plant and industrial piping, announces that its office has been removed to the new Kendall Square Bldg., Cambridge, Mass. It also announces that H. N. Carlson, formerly of the Massachusetts Institute of Technology and Wentworth Institute, is now associated with the firm as engineer of construction and design.

THE CHEMICAL & VACUUM MACHINERY Co., INC., Buffalo, N. Y., has acquired from the Judelson Evapo-Dryer Corp., New York City, all rights to build and market exclusively the apparatus known as the Judelson Evapo-Dryer under Process Patent 1,527,193, Dryer Patent 1,527,192 and Insulator Patent 1,513,595.

CHAS. C. PHELPS, 473 Getty Ave., Paterson, N. J., announces that he and Chas. J. Schmid, his associate, have been appointed Metropolitan New York and New Jersey representatives for the Uehling Instrument Co., the Williams Gauge Co., the Combustion Control Division of the A. W. Cash Co. and the National Boiler Protector Co. Mr. Phelps still retains his former connection with Uehling Instrument Co. as treasurer of that organization. Mr. Schmid was formerly the Boston representative of the same company.

CARL B. LUSCOMBE, formerly superintendent of the Western Division of the Public Service Company of Colorado at Boulder, Colo., has just been transferred from Boulder to Grand Junction to take charge of the Grand Junction Electric Gas & Mfg. Co., which has been acquired by the Public Service Co. of Colorado.

W. B. FOSHAY Co., Minneapolis, Minn., operating the Peoples Light & Power Corp., and other power properties, has acquired the Burlington Traction Co., Military Post Street Railway Co., and the Vergennes Electric Co., all operating at Burlington and Vergennes, Vt., and vicinity. The purchased utilities will be consolidated under a new company to be organized as the Peoples Vermont Hydro-Electric Co.

THE GATINEAU POWER Co., organized by the International Paper Co., 100 E. Forty-second St., New York, as a subsidiary concern to carry out its proposed hydro-electric power development on the Gatineau River, Province of Quebec, has started work on the initial generating stations, with total output of close to 400,000 hp., of which 260,000 hp. will be furnished annually to the Ontario Hydro-Electric Commission for a period of 12 yr.

ILLINOIS POWER & LIGHT Co., Chicago, Ill., is at present carrying on extensive construction work on the addition to its power plant at Danville, Ill. A 12,500-kw. General Electric Co. turbo-generator is being installed, together with four Stirling boilers, each of 750 hp. rated capacity and designed for 350 lb. steam pressure and 200 deg. superheat, accompanied by the customary auxiliaries. Connecting Danville, Urbana, Champaign and Decatur, a 66,000-v. steel tower transmission line is being erected. All design and construction work is being done by the company engineers.

THE GARLOCK PACKING Co., Palmyra, N. Y., announces the opening of a new branch sales office and warehouse at 805 Washington Ave., Houston, Tex.

IRVING E. BROOKE, formerly of Muir & Brooke, has opened an office at 189 W. Madison St., Chicago, for the practice of general engineering design, supervision, investigation, and reports, specializing in power plants, heating, ventilating, plumbing and wiring systems and mechanical equipment.

ACCORDING TO A RECENT announcement, construction of a new power plant of the Ohio Public Service Co., at Dillies Bottom, O., will be commenced this summer, the site having been purchased.

PENNSYLVANIA POWER & LIGHT Co. plans the construction of a new steam power plant at Hummel's Wharf, the project including a railroad spur and a dam. It is expected that this plant will be completed in the summer of 1928. It is reported that the cost of the plant will be about $80,000,000.

EDWARD D. BOTTSFORD has recently resigned from the position of designer of mechanical equipment for Cass Gilbert, architect, to take charge of the sale of heat utilizing devices for the Interstate Co. of Passaic, N. J.

U. S. CIVIL SERVICE COMMISSION announces the following open competitive examinations: Radio Engineer, Associate Radio Engineer, Assistant Radio Engineer, Ceramic Engineer, Materials Engineer, Concrete Engineer and Assistant Chemical Engineer (Pulp and Paper). Applications for these positions should be on file in Washington, D. C., not later than July 27. Full information and application blanks can be obtained from the commission at Washington or from the secretary of the board of U. S. Civil Service Examiners at any post office or custom house.

Books and Catalogs

INDUSTRIAL ELECTRICITY, Part II, by Chester L. Dawes. First Edition, 480 pages, 5½ by 8 in., cloth; 1925, New York, N. Y.; price, $2.75.

This excellent book is the companion volume to Industrial Electricity, Part I, by the same author in 1924, and is devoted to the fundamentals of alternating currents. The first volume was devoted almost entirely to direct current work. Together, the two books constitute one of the clearest works on the fundamental principles of electrical engineering that we have seen.

Throughout, there is a well organized plan which takes the student from the simple to the more complex in a logical manner. While it is essentially a textbook intended for use in courses of the collegiate grade and in advanced courses in trade schools, it should be of value to the man ten years out of college who wishes to brush up on his electrical theory. To the beginner it offers many clear explanations of electrical phenomena, using only the simplest of mathematics. Mechanical and hydraulic analogies are given in many cases, to enable the student to visualize the things which occur in electric circuits.

It is modern in every respect and contains chapter on electron tubes which incorporates many of the late developments in this youngest but by no means unimportant branch of electrical engineering. It also is the first general textbook on fundamental electrical engineering that intimates that the true direction flow of current in a circuit is not from positive to negative as it is usually regarded but from negative to positive as is indicated by the operation of the electron tube. This chapter on electron

tubes is necessarily limited because of space requirements, yet the very fact that it is included is encouraging. It is a quarter of a century ago since Richardson enunciated the law of emission from hot bodies and some fifteen years since Millikan determined the charge of the electron, yet in our textbooks except for a few brief paragraphs the electron has received little consideration. The electron is the fundamental unit in electrical engineering and we look forward to the time when the textbooks will start with a study of the electron and then by a logical method, explain all electrical phenomena in terms of this fundamental unit.

BULLETIN No. 153 of the Engineering Experiment Station of the University of Illinois, entitled "The Effect of Temperature on the Registration of Single-Phase Induction Watthour Meters," contains the report of an investigation which was undertaken to determine the effect of temperature upon the registration of two-wire, single-phase watthour meters. Copies of Bulletin 153 may be obtained without charge by addressing the Engineering Experiment Station, Urbana, Ill.

INGERSOLL-RAND oil engines, Type "PO," are described and illustrated in a catalog just issued by Ingersoll-Rand Co., New York. The bulletin contains interesting data on fuel consumption, details of construction, and many photographs of unusual applications to all types of power plant service.

THE TERRY PAPER MACHINE DRIVE is the title of a 12-page pamphlet issued by The Terry Steam Turbine Co., Hartford, Conn. This drive is an application of the Terry turbine together with an especially designed Terry herringbone reduction gear to the driving of all types of paper machines, to take advantage of the higher steam pressures now in use; to insure constant speed for the paper machines to prevent breaks and to supply exhaust steam suitable for driving in the rolls.

THE ELGIN SYSTEM of Internal Softening and Purifying for steam boilers is described in catalog E-10, issued by Reiter Co. of Elgin, Ill.

MCINTOSH & SEYMOUR CORP., Auburn, N. Y., in an interesting 4-page leaflet discusses the economy of the Diesel engine as compared with the steam engine.

GRAVER ZEOLITE WATER SOFTENERS are described and attractively illustrated in bulletin 509 just issued by the Graver Corp., East Chicago, Ind.

CLARAGE TYPE FD BLOWER for high speed forced draft applications is described in catalog No. 312 just issued by the Clarage Fan Co., Kalamazoo, Mich.

E. J. LAVINO & Co., Philadelphia, Pa., in a 28-page booklet, describes fully the use of Kromepatch-Neutragrog bottoms in forge and heating furnaces.

METALINE, A METAL for bushings or bearing plugs, designed to eliminate the use of lubricants in bearings, is completely described in an illustrated 24-page booklet issued by R. W. Rhoades Metaline Co., Inc., New York City.

ASBESTOS PRODUCTS for the use of public utilities and electrical manufacturers are described in a booklet issued by the Asbestos, Shingle, Slate & Sheathing Co., Ambler, Pa. Among the products described is Ebonized Asbestos Lumber for control boards and panels.

INSTANT WATER HEATER SALES DIVISION, Chicago, Ill., has issued bulletin No. 526 covering Type 26 Instant Copper Tube Water Heaters. This bulletin contains tables of dimensions of the heater together with tables of water capacities of the various sizes.

NICHOLSON SUPER-TRAP, a piston-operated trap with a separate hand blow-off provision, is described by W. H. Nicholson & Co. of Wilkes-Barre, Pa., in a recent bulletin. This is made in cast iron for pressures up to 200 lb. and in cast steel for pressures up to 400 lb.

DEAN HILL PUMP CO., Anderson, Ind., has just issued Bulletin 602, which describes details and applications of its multi-stage centrifugal pumps. These are built either in volute or diffuser type and for drive by motor, steam turbine or internal combustion engine.

STATOR CONSTRUCTION AND FIELD WINDINGS of Century Squirrel Cage Induction Polyphase Motors are described and illustrated in a leaflet issued by Century Electric Co., St. Louis, Mo.

POOLE FLEXIBLE COUPLINGS, which are of the all metal type, lubricated and self-alining, are described and illustrated, together with a table of dimensions, in bulletin 108 just issued by Poole Engineering and Machine Co., Baltimore, Md.

ELECTRIC ELEVATOR EQUIPMENT for various services in office buildings, hotels and the like is described and illustrated in a series of single-page leaflets, Nos. GEA-336 to 345, issued by General Electric Co., Schenectady, N. Y.

ANTHRACITE COAL SERVICE, a magazine devoted to engineering facts for fuel buyers, contains in its fourth issue an interesting short article on power plant costs and another showing a chart comparing prices of coal and oil under given power plant conditions.

VICTAULIC LEAKTITE AND FLEXIBLE JOINTS for Steel and Cast Iron Pipes and Hose are described in Bulletin A, recently issued by the Victaulic Company of America, New York City. This equipment is supplied for compressed air, water, oil, gas and the like, and for pressures from below atmospheric up to 2 t. per sq. in.

LEEDS & NORTHRUP CO., Philadelphia, Pa., has recently issued bulletin No. 985 entitled Frequency Measurement and Control. This bulletin, No. 3 in the Power Plant Series, discusses the problem of accurate frequency control; gives the electrical circuit used in its equipment and gives dimensions and a typical chart from its frequency recorder.

THE CARBONDALE MACHINE CO., Carbondale, Pa., has recently issued Bulletin No. 226, describing the details of construction and installation of Spira-Flo ammonia condensers. These are so designed that the water passing through the condenser is given a swirling motion to obtain better distribution of the cooling effect over the entire surface.

THE BRISTOL CO., Waterbury, Conn., has just issued catalog No. 1700, describing Bristol Tachometers for recording and indicating the speed of rotation of any piece of revolving machinery. These tachometers are electrically operated and permit the recording instruments to be placed at any desired position remote from the machinery to be measured. The bulletin also describes the recording pneumatic tachometer.

Sparks from the Advertising Pages

Where Buyers and Sellers Meet

Conquerors of Time and Distance

The world pays tribute to explorers into the unknown even, as with the recent explorations of the North Pole, when no immediate money value is involved.

The risk, the hazard and the enterprise involved in such expeditions strike a responsive note in each of us, give each man a new pride in his generation and encourage him to meet the embattled forces that face him in his own life.

Nor is it necessary for men imbued with such a spirit to wait for an expedition to the North Pole to satisfy their innate desire for exploration and pioneering.

Time and distance and all the laws that science has outlined lie all about us. In a thousand and one ways they tempt us to new conquests of the visible limitations they have placed on the lives of us all.

As new explorations are made into natural laws and new routes are charted and followed, so are the vistas of future explorations increased.

Hundreds of thousands of explorers are giving time and life, laying aside opportunities of ease and pleasure, to follow hidden trails of abstract science or to lead the multitude into newly discovered ways of getting more out of life.

In laboratories and power plants, in offices and homes, the pioneer spirit of men leads them to lavish strength and wealth to satisfy the urge toward further progress.

This constantly increasing effort of modern exploration cannot be explained by the desire for the almighty dollar. That, as an end and purpose, cannot even explain the effort toward improvement of the so-called soulless corporations!

Somewhere within us all there is a spirit that "bids us neither sit nor stand, but go."

Call it what you will, this spirit has been in men of all ages and is growing in the power it exercises in people from generation to generation.

Thousands of years ago it sent men out on the sea in puny boats, and kept them out, each generation building better ships and driving them farther.

Overland such men have trekked. Into the earth they have explored and brought to the surface many ores.

On the earth they have constantly formed new combinations of materials and found new ways of applying their products, and so have dug, and hammered and shaped this, the civilization of today.

Wealth alone, the lust for which is set down in histories as the prompting cause of ancient explorations, cannot have been the primary cause. Thousands of men must have lived with a far greater desire for wealth than that of the men who sailed from many ports toward the rim of the world, ostensibly in search of the gold and jewels of the Indes.

Desire for wealth alone cannot account for the enterprises and sacrifices of today. Men do not risk their earnings in new companies, plan and build for one, two or three generations hence, give their lives to inventions and experiments, to the end that they or their descendants may have a few more dollars.

Nowhere will you find good work done that way. Often you will find men who are doing such work declaring that money is their end and aim!

If we could "own up" to ourselves we would find we are constantly exploring, ever seeking to satisfy that inward urge to advance toward a far distant light of knowledge and a higher plane of harmony of life and natural law.

To save themselves from derision, men talk of money as their objective. And the very men who deride, often turn about and secretly help toward great enterprises to satisfy their own inner desire to give a bit of themselves toward advancement.

What, then, is this power that persists throughout the urgent necessities of everyday life?

May it not be an inward desire for self-mastery and an unuttered realization that mastery of environment is the only way to mastery of self?

Are we not excusing our higher selves to our practical selves when we plan new plants, work on new machines, strive for new standards of operation on a money basis, many of which enterprises, any actuary can tell us, we shall never live to see in full operation and application?

Man's every "polar expedition," carried on day by day, in shop, foundry, engine room, office or factory, is priceless to his inner life, to mastery of self. His enterprises that overlap into those of lives that shall succeed him are linking him with the eternal.

No great discoveries, scientific or material, have been made without such journeys, physical or mental, into the unknown.

In our own field, engineers of today are men with persevering vision who explore other important power plants, and the machinery and equipment that are in them, and thereby attain greater self-mastery in their profession.

Power Plant Engineering is a magazine for such men. It carries them into the important power plants of the country. Through it important improvements and the perfected products in machinery, equipment and supplies are brought to their attention.

They read it to conquer time and distance for themselves; to help them to conquer time and distance for their own and future generations.

Machinery, Equipment and Supplies Used In The Production and Transmission of Power

Under the heading of each product listed will be found the names of the manufacturers of that product. The index to advertisers, next to the back cover, gives the page numbers on which the manufacturers' descriptive advertisements appear.

AIR COMPRESSORS
Allen & Billmyre Co., Inc., New York.
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Bethlehem Shipbuilding Corp., Bethlehem, Pa.
Dean Bros. Co., Indianapolis.
De Laval Steam Turbine Co., Trenton, N. J.
Gardner Governor Co., The, Quincy, Ill.
Ingersoll-Rand Co., New York.
Murray Iron Works Co., Burlington, Iowa.
Nordberg Mfg. Co., Milwaukee.
Worthington Pump & Machinery Corp., New York, N. Y.
Yeomans Bros. Co., Chicago.

AIR FILTERS
Allen & Billmyre Co., Inc., New York.
Cooling Tower Co., Inc., The, New York.

AIR WASHERS.
Cooling Tower Co., Inc., The, New York.
New York Blower Co., Chicago.

ALARMS, HIGH AND LOW WATER.
Hills-McCanna Co., Chicago.
Huyette Co., Inc., The Paul B., Philadelphia.
Northern Equipment Co., Erie.
Williams Gauge Co., The, Pittsburgh.
Wright-Austin Co., Detroit.

ARCHES, BOILER AND COMBUSTION.
Betson Plastic Fire Brick Co., Inc., Rome, N. Y.
Brady Conveyors Corp., Chicago.
Burke Engineering Co., Holland, Mich.
Detrick Co., M. H., Chicago.
Harbison - Walker Refractories Co., Pittsburgh, Pa.
Hofft Co., The M. A., Indianapolis, Ind.
McLeod & Henry Co., Troy, N. Y.
Obermayer Co., The S., Chicago.
Queen's Run Refractories Co., Inc., Lock Haven, Pa.
Quigley Furnace Specialtes Co., Inc., New York.

ASH BIN GATES AND DOORS.
Allen-Sherman-Hoff Co., The, Philadelphia, Pa.
Brady Conveyors Corp., Chicago.
Conveyors Corp. of Amer., Chicago.
Hagan Co., George J., Pittsburgh.

ASH HANDLING SYSTEMS.
Allen-Sherman-Hoff Co., The, Philadelphia, Pa.
Brady Conveyors Corp., Chicago.
Conveyors Corp. of America, Chicago, Ill.
Detrick Co., M. H., Chicago.
Hagan Co., George J., Pittsburgh.
Link-Belt Company, Chicago.
Stearns Conveyor Co., The, Cleveland, Ohio.
Stephens-Adamson Mfg. Co., Aurora, Ill.
Webster Mfg. Co., The, Chicago.

ASH TANKS.
Conveyors Corp. of America, Chicago.
Hagan Co., George J., Pittsburgh.

BABBITT METAL.
Magnolia Metal Co., New York.

BEARING METAL.
Magnolia Metal Co., New York.
Strong, Carlisle & Hammond Co., Cleveland, Ohio.

BEARINGS.
National Tube Co., Pittsburgh.

BELT CONVEYORS.
Jeffrey Mfg. Co., The, Columbus, O.
Stearns Conveyor Co., The, Cleveland, Ohio.
Stephens - Adamson Mfg. Co., Aurora, Ill.
Webster Mfg. Co., The, Chicago.

BELT DRESSING.
Dixon Crucible Co., Jos., Jersey City, N. J.
Standard Oil Co. (Indiana), Chicago, Ill.
Stephenson Mfg. Co., Albany.

BELTING.
New York Belting & P'k'g Co., New York.
Quaker City Rubber Co., Philadelphia.
United States Rubber Co., New York, N. Y.

BELTING, SILENT CHAIN.
Link-Belt Co., Chicago, Ill.
Morse Chain Co., Ithaca, N. Y.

BLOWERS, FAN & FURNACE.
Air Preheater Corp., The, New York.
Coppus Engineering Corp., Worcester, Mass.
De Laval Steam Turbine Co., Trenton, N. J.
Ingersoll-Rand Co., New York.
New York Blower Co., Chicago.
Terry Steam Turbine Co., Hartford, Conn.
Wing Mfg. Co., L. J., New York.

BLOWERS, FORCED DRAFT.
New York Blower Co., Chicago.
Sturtevant Co., B. F., Hyde Park, Mass.

BLOWERS, PORTABLE.
Allen & Billmyre Co., Inc., New York.
Permutit Co., New York, N. Y.
Scaife & Sons Co., Wm. B., Pittsburgh.

BOILER FRONTS.
McLeod & Henry Co., Troy, N. Y.

BOILER MOUNTINGS.
Lunkenheimer Co., Cincinnati.

BOILER SEAM PROTECTORS.
National Boiler Protector Co., Dayton, Ohio.

BOILER SETTING CEMENT.
Betson Plastic Fire Brick Co., Rome, N. Y.
Botfield Refractories Co., Philadelphia, Pa.
General Refractories Co., Philadelphia, Pa.
Harbison - Walker Refractories Co., Pittsburgh, Pa.
Huyette Co., Inc., The Paul B., Philadelphia.
Obermayer Co., The S., Chicago.
Queen's Run Refractories Co., Inc., Lock Haven, Pa.
Quigley Furnace Specialties Co., Inc., New York.

BOILER SETTINGS.
Betson Plastic Fire Brick Co., Inc., Rome, N. Y.
Botfield Refractories Co., Philadelphia, Pa.

To Find the Manufacturers' Advertisements of Products Listed Here, See Index Page 154

Sturtevant Co., B. F., Hyde Park, Mass.
Marion Mach., Fdry. & Supply Co., Marion, Ind.
Pilley Pkg. & Flue Brush Mfg. Co., St. Louis, Mo.
Vulcan Soot Cleaner Co., Du Bois, Pa.
Webster, Howard J., Philadelphia, Pa.

BLOWERS, STEAM.
Schutte & Koerting Co., Philadelphia.

BLOWERS, TUBE.
Marion Mach., Fdry. & Supply Co., Marion, Ind.

BLOWERS, TURBINE.
Allen & Billmyre Co., Inc., New York.
Moore Steam Turbine Corp., Wellsville, N. Y.
Wing Mfg. Co., L. J., New York.

BOILER BAFFLES.
Betson Plastic Fire Brick Co., Rome, N. Y.
Boiler Engineering Co., Newark, N. J.
McLeod & Henry Co., Troy, N. Y.
Quigley Furnace Specialties Co., Inc., New York.

BOILER CAP CLEANERS.
Lagonda Mfg. Co., Springfield, Ohio.

BOILER CASING.
Walsh & Weidner Boiler Co., The, Chattanooga, Tenn.

BOILER COMPOUND.
Botfield Refractories Co., Philadelphia, Pa.
Dearborn Chemical Co., Chicago.
Hawk-Eye Compound Co., Blue Island, Ill.
McLeod & Henry Co., Troy, N. Y.
Paige & Jones Chemical Co., Inc., New York.

BOILER COMPOUND FEEDERS.
Hills-McCanna Co., Chicago, Ill.

BOILER COVERINGS.
Celite Products Co., New York.

BOILER FEED WATER, PURIFYING APPARATUS.
Griscom-Russell Co., New York.
Paige & Jones Chemical Co., Inc., New York.
General Refractories Co., Philadelphia, Pa.
Harbison - Walker Refractories Co., Pittsburgh, Pa.
McLeod & Henry Co., Troy, N. Y.
Obermayer Co., The S., Chicago.
Queen's Run Refractories Co., Inc., Lock Haven, Pa.
Quigley Furnace Specialties Co., Inc., New York.
Walsh & Weidner Boiler Co., The, Chattanooga, Tenn.
Webster, Howard J., Philadelphia, Pa.

BOILER SKIMMERS.
Sims Co., The, Erie, Pa.

BOILER TUBE CLEANERS.
Lagonda Mfg. Co., Springfield, Ohio.
Liberty Mfg. Co., Pittsburgh.
Pierce Co., The Wm. B., Buffalo, N. Y.
Roto Co., The, Hartford, Conn.

BOILER TUBES.
Babcock & Wilcox Tube Co., The, Beaver Falls, Pa.
Bethlehem Steel Co., Inc., Bethlehem, Pa.
Murray Iron Works Co., Burlington, Iowa.
National Tube Co., Pittsburgh.
Reading Iron Co., Reading, Pa.
Scully Steel & Iron Co., Chicago.

BOILER WALL COATINGS.
Botfield Refractories Co., Philadelphia, Pa.

BOILERS.
Babcock & Wilcox Co., N. Y.
Badenhausen Corp., Cornwells Heights, Pa.
Casey-Hedges Co., The, Chattanooga, Tenn.
Connelly Boiler Co., The D., Cleveland, O.
Edge Moor Iron Co., Edge Moor, Del.
Heine Boiler Co., St. Louis.
Kingsford Fdry. & Mach. Wks., Oswego, N. Y.
Murray Iron Works Co., Burlington, Iowa.
Nuway Boiler & Engineering Co., Chicago.
Springfield Boiler Co., Springfield, Ill.
Union Iron Wks., Erie, Pa.
Vilter Mfg. Co., Milwaukee.
Walsh & Weidner Boiler Co., The, Chattanooga, Tenn.
Webster, Howard J., Philadelphia, Pa.
Wickes Boiler Co., Saginaw.

BREECHINGS.
Littleford Bros., Cincinnati, O.

BRICKS, FURNACE LINING.
Norton Co., Worcester, Mass.

BRUSHES, DYNAMO AND MOTOR.
Calebaugh Self-Lubricating Carbon Co., Inc., Philadelphia.
Dixon Crucible Co., Jos., Jersey City, N. J.

BRUSHES, GRAPHITE.
Dixon Crucible Co., Jos., Jersey City, N. J.

BRUSHES, WIRE.
Pilley Pkg. & Flue Brush Mfg. Co., St. Louis, Mo.

BUCKET ELEVATORS.
Jeffrey Mfg. Co., The, Columbus, O.
Link-Belt Company, Chicago.
Webster Mfg. Co., The, Chicago.

BUCKETS, COAL HANDLING
Jeffrey Mfg. Co., The, Columbus, O.

CAR DUMPERS.
Wellman - Seaver - Morgan Co., The, Cleveland, Ohio.

CARRIERS, PIVOTED BUCKET.
Jeffrey Mfg. Co., The, Columbus, O.
Webster Mfg. Co., The, Chicago.

CASTINGS.
Bethlehem Steel Co., Inc., Bethlehem, Pa.
Fuller - Lehigh Co., Fullerton, Pa.
Hills - McCanna Co., Chicago.
Neemes Fdry. Inc., Troy, N. Y.

CEMENT, ASBESTOS.
New York Belting & P'k'g. Co., New York.

CEMENT, FURNACE.
Betson Plastic Fire Brick Co., Rome, N. Y.
Botfield Refractories Co., Philadelphia, Pa.
General Refractories Co., Philadelphia, Pa.
Harbison - Walker Refractories Co., Pittsburgh.
McLeod & Henry Co., Troy, N. Y.
Norton Co., Worcester, Mass.
Queen's Run Refractories Co., Inc., Lock Haven, Pa.
Quigley Furnace Specialties Co., Inc., New York.

CEMENT GUNS.
Cement-Gun Co., Inc., Allentown, Pa.

CEMENT, HIGH TEMPERATURE.
Botfield Refractories Co., Philadelphia, Pa.
General Refractories Co., Philadelphia, Pa.
Harbison - Walker Refractories Co., Pittsburgh, Pa.
Johns-Manville, Inc., New York.
McLeod & Henry Co., Troy, N. Y.
Norton Co., Worcester, Mass.
Obermayer Co., The S., Chicago.
Quigley Furnace Specialties Co., Inc., New York.

CEMENT, IRON.
Smooth-On Mfg. Co., Jersey City, N. J.

CHAIN WHEELS.
Babbitt Steam Specialty Co., New Bedford, Mass.

CHAINS, DRIVE.
Link-Belt Company, Chicago.
Morse Chain Co., Ithaca, N. Y.

CHIMNEYS.
American Chimney Corp., New York.
Springfield Boiler Co., Springfield, Ill.

CIRCUIT BREAKERS.
Cutter Co., The, Philadelphia.

CLEANERS, BOILER TUBE.
General Specialty Co., The, Buffalo, N. Y.
Lagonda Mfg. Co., Springfield, Ohio.
Liberty Mfg. Co., Pittsburgh, Pa.